Responding to the Grand Challenge: The Quantified Community and SimNYC: Instrumenting, Measuring, and Modeling the City

CENTER FOR URBAN SCIENCE+PROGRESS

NYU-poly

COURANT INSTITUTE OF MATHEMATICAL SCIENCES

With Initial Participation By:

RELATED

CISCO

Principal Investigators:

Dr. Constantine E. Kontokosta
Deputy Director, NYU CUSP
1 Metrotech Center, 19th Floor
Brooklyn, NY 11201
ckontokosta@nyu.edu
347-409-2880

Dr. Denis Zorin
Professor of Computer Science/Mathematics
Courant Institute
719 Broadway, 12th Floor
New York, NY 10003
dzorin@cs.nyu.edu
212-998-3405

Dr. Claudio Silva
Professor of Computer Science, NYU-Poly
Head of Disciplines, CUSP
1 Metrotech Center, 19th Floor
Brooklyn, NY 11201
csilva@nyu.edu
(646) 997-0504

Other Investigators:

Dr. Fletcher Griffis
Professor and Director
Construction Technology, NYU-Poly
6 Metrotech Center, RH 407
Brooklyn, NY 11201
griffis@poly.edu
718-260-3717

Dr. Masoud Ghandehari
Professor, Head - Urban Observatory
NYU-Poly and CUSP
1 Metrotech Center, 19th Floor
Brooklyn, NY 11201
masoud@poly.edu
718-260-3441

Dr. Steven Koonin
Director
CUSP
1 Metrotech Center
Brooklyn, NY 11201
sek9@nyu.edu

SECTION I – The Quantified Community and SimNYC as Grand Challenge – Instrumenting and Modeling the City

The Center for Urban Science and Progress (“**CUSP”**) is a unique public-private research center that uses New York City as its laboratory and classroom to help cities around the world become more productive, livable, equitable, and resilient. CUSP observes, analyzes, and models cities to optimize outcomes, prototype new solutions, formalize new tools and processes, and develop new expertise/experts. These activities will make CUSP the world’s leading authority in the emerging field of “Urban Informatics.”

CUSP was created by New York University, NYU-Poly, a consortium of world-class universities, and prominent international tech companies as a response to a challenge put forth by New York City to create an applied science campus that will make the City a world capital of science and technology, and dramatically grow its economy. It is a principal objective of CUSP to address the critical challenges facing cities, including but not limited to, infrastructure, technology integration, energy efficiency, transportation congestion, public safety, and public health.

Given the importance of cities to the world’s future, the interaction of urban infrastructure, environment, and people must be better understood. While advances in data collection and modeling tools have improved planning and operations within specific urban domains, new sensing technologies (both proliferated *in situ* and synoptic) enable new sources of data that could be harnessed to understand and improve urban life. For example, mobile phones that can capture, classify, and transmit audio, video, and location data create the opportunity to actively engage citizens in this process and, in so doing, overcome persistent challenges in large-scale data collection. This “participatory sensing” allows researchers to explore critical quality of life issues previously unobservable, such as health status and physical activity. Synoptic observations in diverse spectral bands or with RADAR or LiDAR offer complementary ways of sensing the city. However, attempts to collect new data from urban sensors remain episodic and insular – video imagery from cameras collected for public safety purposes is rarely used to understand mobility, air sensors deployments are limited in space and time, etc.

While fully instrumenting an entire city would require a massive commitment of time and resources, significant progress could be achieved at the neighborhood scale by focusing diverse, comprehensive, and persistent real-time data collection and analysis on a “quantified community” (QC). The resulting unique experimental environment would provide a testing ground for new physical and informatics technologies, policies, and behavioral interventions, allowing unprecedented studies in urban engineering, urban systems operation and planning, and the social sciences.

The deployment of the QC will allow us to create a full-scale simulation of New York City, “SimCity for real” or “SimNYC”, which is a faithful multiscale description in silico of the city and its inhabitants. Such a capability would be an extraordinarily useful tool for city operators and planners, for disaster management and response, for policy makers, for social scientists, for the private sector, and for public education and outreach. While SimNYC does not currently exist, plausible advances in urban “Big Data” and simulation technologies over the next decade, coupled with the unique and comprehensive data collection platform of the QC, would enable undertaking the grand challenge of building SimNYC. NYU is well positioned to seize this opportunity with its strengths in fundamental modeling and data science, engineering, the social sciences, and its investment in CUSP.

In order to build SimNYC, we need to be able to model the dynamics and interactions of the physical infrastructure of the city (buildings, roads, tunnels, bridges, transit, utilities, …), the environment (meteorology, pollution, noise), and the people (health, location, activity, economics, communications,

…); at very high resolutions across multiple scales, building on a foundation of detailed measurements of all aspects of the urban environment and population.

Modeling and measuring a "slice of the city" is an extremely important step of building SimNYC and data from a QC of sufficient scale could be used to calibrate and validate models of the urban infrastructure, environment, and population. Theories of urban form and function could be developed, hypotheses could be tested, and interventions could be measured to evaluate their effectiveness and support evidence-based decision-making in the urban context. Understanding various quality-of-life metrics would promote substantial improvements in the lives of urban dwellers and have important implications for economic development indicators such as land and real estate values and tax assessments. Sensors would measure energy and water consumption in buildings, stormwater runoff quantity and quality, sound levels and classifications, air contamination and pollution plumes, and any number of other conditions. The flow of people in, out, and within the QC could be monitored, creating the opportunity to use agent-based modeling and simulation techniques to recognize, predict, and optimize movement patterns across the city. Measurement of health, nutrition, communications, and economic activities would yield important insights. As importantly, new technologies could be tested and demonstrated, creating opportunities for entrepreneurs to better understand – in real-time – their impacts beyond an individual building or system.

We are particularly interested in the measurement and analysis of data relating to infrastructure, environment, and people. Examples of the types of information we are interested in monitoring and collecting are shown in **Figure 1**.

Figure 1: Categories of Data Collection

Infrastructure

- Buildings
  - Resource consumption
  - Indoor environmental quality
- Solid waste
- Stormwater management
- Power generation & distribution
- Condition (failure prediction)

Environment

- Carbon emissions
- Particulate levels and concentrations
- Noise
- Climate conditions and microclimate
- Use of public space

People

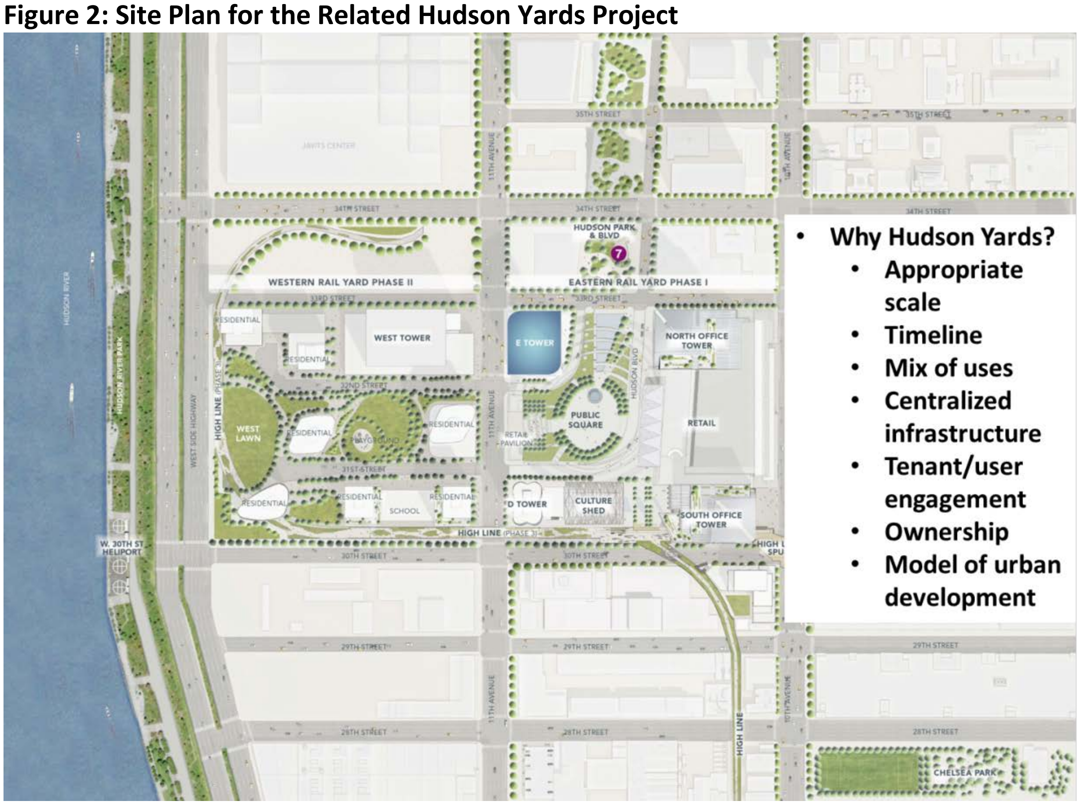
- Health, nutrition, and activity levels
- Social networks
- Mobility
- Metagenomics
- Behavior

SECTION II – Technical Approach and Implementation Plan

A fully instrumented urban neighborhood could be an important scientific and educational platform and a test bed for interventions to improve quality of life. It would also yield a rich, long-term source of research activity and entrepreneurial opportunity. The Hudson Yards development, led by the Related Companies, magnifies this significance by its scale and ownership structure, making it an ideal long-term QC. Situated in New York City, Hudson Yards will encompass more than 26 acres, with approximately 15,000,000 square feet of space proposed and encompassing district-level infrastructure with high performance buildings (as shown in **Figure 2**). The data collected, models developed, and technologies tested and deployed in such a community would provide important lessons, not only for retrofitting existing, aging industrial cities (like New York, Chicago, and London), but also for the planning, design, and utilization of technologies in new-build cities. To put the Hudson Yards development in context, it is proposed to encompass more built area than Masdar City in Abu Dhabi and be home to more than five times the number of people than in Dongtan City in Shanghai. Hudson Yards will have a diverse ecology, with waterfront areas, green space, and a diverse range of building types and uses, which would ensure the replicability of lessons learned.

Dr. Kontokosta has negotiated an unprecedented opportunity to deploy the QC at the Hudson Yards development site and is currently finalizing the formal agreement between CUSP and the Related Companies, owner/developer of the Hudson Yards project.

Figure 2: Site Plan for the Related Hudson Yards Project



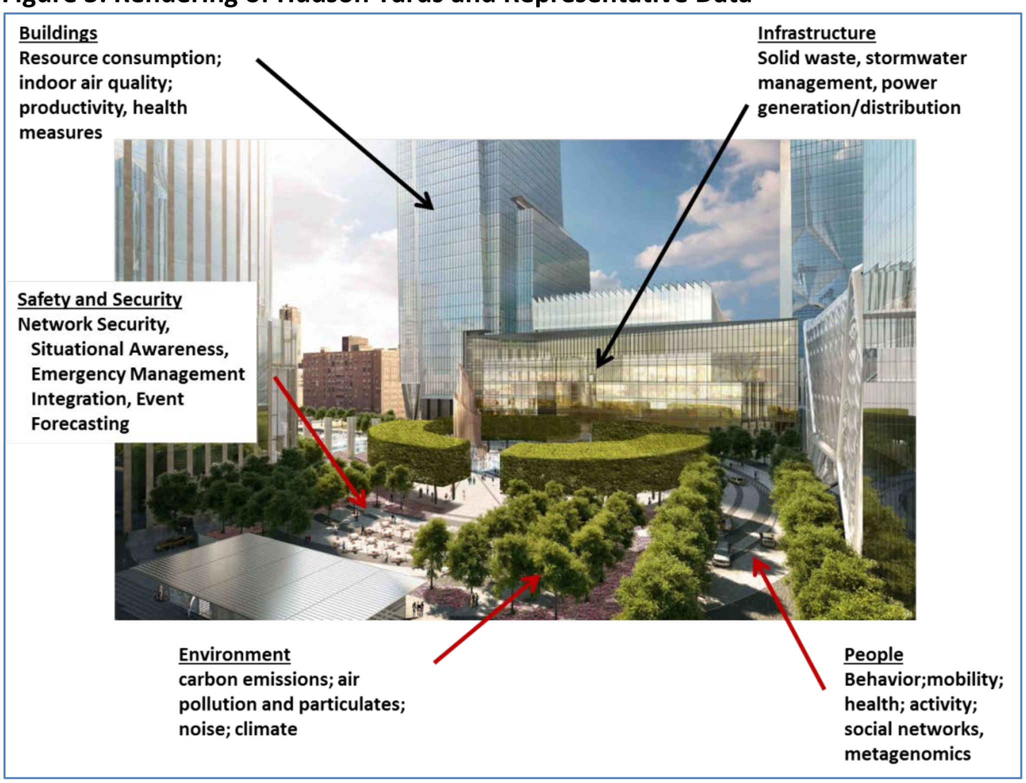
Through the Related-CUSP QC collaboration, CUSP will develop a design manual for sensor technology and instrumentation capability in the Hudson Yards development, and to collect, analyze, and interpret data generated through such instrumentation. This design manual would be both generic in scope and specific to the Hudson Yards site. The concept is to develop a methodology for the implementation and deployment of the QC platform in any district-scale development or existing neighborhood. A fully instrumented urban neighborhood would be an important scientific and educational platform and a test bed for interventions to improve quality of life. It is expected that this project will generate significant value for cities and future urban development through the ability to measure, monitor, and analyze critical infrastructure and operational systems, to evaluate the effects – real-time – of various interventions, and to serve as the basis for the SimNYC urban simulation model.

The CUSP QC would be a landmark opportunity to create both a model for future urban development and a platform for real-time research in the operations and interaction of urban systems.

The QC will provide:

- The data necessary to calibrate and develop simulations of urban systems (examples shown in **Figure 3**)
- Integrated analysis of data from installed building systems
- The ability to test and evaluate interventions – including operational and management strategies — with real-time feedback
- The ability to study behavioral implications of various technologies
- Opportunities for the long-term study of resident/worker outcomes
- A “plug and play” environment to test, demonstrate, and evaluate appropriate urban and green building technologies, facilitated by the use of BIM as roadmap for sensor locations and operations and by incorporating this goal into the planning process and infrastructure design to allow for adaptability over time.

Figure 3: Rendering of Hudson Yards and Representative Data



These capabilities create value for the QC district through:

- The measurement, monitoring, and analysis of critical systems and infrastructure
- A better understanding environmental conditions and indicators, both indoors and outdoors, and the ability to react to sub-optimal conditions
- The ability to collect, process, and utilize large amounts of data to improve quality of life for residents, workers, and visitors

- The measurement and analytics to support operational efficiencies to lower operating expenses
- The potential to generate greater market demand for space and attract investment
- The opportunity to develop and test business models, such as new leasing structures and performance-based revenue and expense models, and analyze the economic effects of data-driven optimization of operations, resource flows, and quality-of-life indicators

To accomplish the goals of the QC, we will within the next two years:

1. Develop a team of faculty researchers and industrial scientists (QC Project Team) to define the technical capabilities, database architecture and management processes, and specific sensor technologies need to support the CUSP QC Project.
2. Convene several workshops and meetings, working with the Related Project Team, to define initial priorities and opportunities to integrate sensors and instrumentation into the HY development. These priority areas might include, but are not limited to:
    a. Waste management and reduction
    b. Building energy and water performance and efficiency
    c. Building and infrastructure resilience, adaptability, and survivability
    d. Noise monitoring and mitigation strategies
    e. Air quality monitoring and mitigation strategies
3. Work to create a clearinghouse for the CUSP QC Project in the areas of sensor technology, data management, and relevant technical and IT systems
4. Support the use of Building Information Modeling (BIM) by the Related Project Team to develop a virtual framework for the CUSP QC at Hudson Yards deployment strategy
5. Begin to convene industry partners to support the deployment of the CUSP QC at Hudson Yards. These CUSP QC Partners may be existing CUSP Partners or those currently unaffiliated with CUSP. New CUSP QC Partners will be determined by the CUSP QC Project Team in consultation with Related
6. Define and develop a strategy for the deployment of pilot project(s), as feasible, within the initial construction phase of Hudson Yards and the initial phase of the Grand Challenge grant

- In support of these goals, Related has tentatively agreed to:
    1. Identify a Related point of contact to collaborate with and support the CUSP QC Project Team and act as a liaison between CUSP and the Related HY design team
    2. Provide the CUSP QC Project Team with access to the HY design team, technical drawings, and project site to support the planning and deployment of pilot project(s) and to evaluate and develop the implementation/ deployment strategy of the CUSP QC Project at Hudson Yards
    3. Provide the CUSP QC Project Team with information as needed to effectively analyze alternative technologies and their potential impacts on operations and quality of life and usefulness in collecting and analyzing data
    4. Allow the CUSP QC Project Team to install equipment to support pilot project(s), as defined by the CUSP QC Project Team and mutually agreed to by CUSP and Related
    5. Work with the CUSP QC Project Team to develop a Phase II long-term deployment strategy and implementation plan

There are precedents in modeling other systems of a comparable complexity and scope. Computer models of vehicles, engines, structures and all types of consumer items are commonly used dramatically reduce design and manufacturing costs while improving performance. Weather models deal with interacting radiation, fluid, and chemical processes; climate models extend the scope to the oceans, cryosphere, and biogeochemical processes; and integrated assessment models go even further to embrace social, technical, and economic dynamics. Closer to the hypothetical SimNYC, simulation models of traffic, land use and epidemiology already find useful although still limited application.

A number of important problems would need to be solved constructing SimNYC; some of them find analogs in the modeling activities described in the previous paragraph. Below, we describe two well defined problem areas that need to be addressed.

UrbanGIS

In order to build SimNYC, we need to develop technology able to handle city-scale models of everything “physical” about the city. Take a single building as an example: we would like to have its detailed geometry, the properties of all materials and finishes, location of wiring, water pipes, internal support structure etc. However, simply acquiring sufficiently complete information about a building is not enough: the buildings undergo constant changes, which, to the extent the data on the changes is available, the computer model should reflect these changes. We identify several important challenges related to model construction, maintenance and use.

Model quality. Using a model as a platform for simulation imposes additional stringent requirements both on model consistency and robustness of simulation tools: for example, minor geometric inaccuracies may result in non-water-tight roof in a model, behaving very differently from the actual building. Small gaps, overlaps and other types of inconsistency may have a dramatic effect on noise propagation and mechanical stability.

While building information modeling (BIM) technology is starting to be available for new construction and helps us to achieve the goal of having simulation-ready models, many challenges remain, which need to be addressed by a combination of adapting and developing tools for model quality improvement as well as developing new simulation methods targeting noisy, incomplete and inconsistent inputs. This type of geometry processing and simulation tools are of significant importance in computer graphics applications and the PIs have an extensive experience developing and applying this type of techniques. The Hudson Yards project will make extensive use of BIM for design and construction planning. We will have access to these BIM models, which will provide the foundation for simulation capability.

Automatic generation and completion. Furthermore, modeling even a few blocks of a city the scale of New York present further challenges. For many, if not most buildings, models will need to be built, potentially from a combination of LIDAR, photographs, city information and manual input. Most likely, for many if not most buildings available data is incomplete. We will apply automated procedural generation techniques that, given a few parameters, can create “plausible” buildings that can be used for large-scale simulation purposes. To use data-driven procedural generation, a realistic “database” of buildings and characteristics; Dr. Kontokosta has started to develop such a database with the goal of modeling building energy characteristics, with detailed data for over 15,000 large NYC buildings. The Hudson Yards project will use CAD three-dimensional design models of each structure, combined with the BIM models, which will be an ideal framework for the simulation model design and calibration.

Scalability. Another challenge is scale. We need tools able to query, inspect, and visualize such models. The models are likely to be of a complexity that is orders of magnitude higher compared to the state-of-the-art GIS systems; few publicly available tools suitable for managing such volumes of heterogeneous geometric and physical data are available.

Modeling/Simulating Humans and Collections of Humans
As already mentioned, besides the infrastructure, we would like to be able to model and simulate the people (location, health, activity, economics, communications, …) and their interactions. One way to do this would be to completely instrument the environment and the people in the environment. In the recent past, this was nearly impossible since any solution would be overly obtrusive and it would greatly impact how individuals behaved.

Now, due to the use of computers, cheap sensors, and web technology, much of the work of "tracking" someone is already being done for us. We posit that a combination of currently available technology will get us a significant fraction of what we need to do know to model a person's behavior. For instance, imagine having access to the following electronic bread crumbs of a person: their Facebook, Withings, Twitter, Fitbit, Foursquare, Google search history, Google plus, Google calendar, and Strava information. This is all information that many people share with their "friends". Depending on how active they are on keeping track of their electronic life, this contains what they eat, how much they weigh, their exercise routine, who they meet, communicate, etc. We envision developing technology for aggregating all this information.

The next level of information that is not normally "given" to friends includes grocery shopping, access to bank accounts and credit card information (e.g., mint.com and pageonce), and health records. Much of this information can also be shared electronically in some way by individuals, and could potentially be consolidated in some form.

Given even some subset of this information, we believe we can revolutionize agent-based modeling and allow for realistic modeling of people behavior and interactions. While a wealth of sophisticated agent-based tools exist (Repast, MASON, Breve and many others) including Repast SC++, a toolkit intended for very-large scale problems, most systems are not data-driven, are not fully integrated with physical simulation and environments or do not scale well. Our goal will be to build on existing technology both on agent-based modeling and simulation/geometry modeling side, and develop integrated systems enabling exploration of complex interactions between social networks, locality and physical conditions.

Data-driven agents. Majority of agent systems now are rule-based, but significant progress was made incorporating data-driven techniques at all levels, from low-level physically-based control to high-level behaviors. We will work to integrate these approaches with an industrial-strength agent-based modeling system, specifically looking to take full advantage of the data collected as outlined below.

Integration with simulation of environment and engineering systems. At the initial stage, our primary goal would be a one-way coupling between agent-based and environmental (climate, structural and other) simulation, with the outputs of the environmental simulation affecting the agent behavior. Even such one-way coupling presents a variety of challenges, due to disparities in spatial and temporal simulation scales. For example the agent behavior may be affected in strong ways by highly localized/transient noise or wind, requiring precise resolution at the agent's location and simulation of stochastic environmental effects, while the global city- or block-scale simulation may not capture these effects properly. We will work to design the global simulations in a way that adapt resolution in space and time for faithful interaction with agents.

Our longer-term goal is to develop a more comprehensive 2-way coupling, including effects of agents on the environment, to be able to capture such effects as the effects of human presence on the heat distribution (e.g., human heat has major impact on heat distribution in a building, if large numbers of people are present, such as government buildings and schools).

Another important coupling is between agent-based system and engineering system simulation (power, water, gas, etc.). Techniques and tools for this type of simulation are well-developed, and from the point of view of such systems, human and environment changes result in changes in loads or other types of inputs; again, as it is the case for environment simulation, agent-based simulation and engineering simulation may be running at different time and spatial scales, requiring aggregation of agent behaviors over space (e.g., all people on a floor or building) and time (e.g., averaged electric load over an hour), but it is also important to detect and simulate common coherent behaviors: simultaneous increase in loads due to an external event: e.g., increase in the volume of phone calls due to a sudden traffic disruption, or a jump in electricity consumption around the time people return from work.

SECTION III – MILESTONES AND METRICS OF SUCCESS

Key Metrics and Milestones for Phase I of the QC

The initial output of Phase I will be a design guidebook for the QC, which will include elements relating to physical sensor deployment (both in-situ and synoptic), data collection and integration processes, data security and storage, and on-going operations management of both the physical equipment and infrastructure and flows of information.

- Initial Workshops – CUSP will host three (3) workshops designed to bring together key project team members, relevant faculty, and industry and agency partners. Each workshop will be measured based on attendance and output in the form of a working paper relating to particular phase of the QC/SimNYC design and deployment strategy.
- Identification of Key Partners – this quantifiable metric will establish the number and contribution of QC/SimNYC partners. Partners are expected to provide R&D expertise, equipment and technology, and access to data.
- Year 1 Progress Report on the QC Design Manual – at the end of year 1, the team will develop a preliminary draft, based on workshop outputs and team meetings, for the framework of the QC/SimNYC deployment.
- Identification of Pilot Project – the CUSP team will work with Related to identify one Pilot Project for the commercial building currently under construction at the site. This will include controls and sensor networks to measure building condition; energy, water, and waste consumption; and occupant condition and mobility. Implementation of the Pilot Project will occur, assuming the project schedule progresses as anticipated, within the initial two-year Grand Challenge grant period.
- Integration of BIM Models – the CUSP team will work with Related to utilize Related's project BIM models as the basis for the QC deployment roadmap and SimNYC baseline.
- Final Deliverable – the QC Design Manual, which outlines the full implementation strategy for the QC project, together with a commitment to move forward by Related or in another suitable location.

UrbanGIS milestones:

1) Our first major milestone is the design and initial implementation of the UrbanGIS framework. In particular, we need to design the data management subsystem to be scalable to very large and detailed models. Another important aspect of the design is to provide provenance support, as to allow for multiple versions of models to be maintained by the system. A final major design goal is rendering efficiency to allow for very large models to be supported by the system.

2) Our second major milestone is to design a parameterized modeling system that is able to generate realistic models of buildings and neighborhoods easily and with minimal user input. We envision designing a parameterized shape-editing framework that can be trained using existing building models. We plan to allow the systems to not only generate geometry, but also to allow for other variables to be models, including material properties.

3) Finally, we plan to use the models for simulation purposes. For instance, we plan to work on sound propagation algorithms that support both the inside and outside of the buildings. For instance, it should be possible to understand the noise characteristics of a given unit based on external criteria, including hour of the day and occupancy in other units (do your neighbors have kids?). It should also be possible to perform simulations of other quantifies, including heat, thus allowing to know how to optimally weatherize a unit.

Modeling/Simulating Humans and Collections of Humans milestones:

1) A key piece to be able to model realistic human behavior is to be able to track their behavior. We plan to design a DataAggregator tool that will support the integration of many different data sources across multiple tools, including Facebook and Twitter. This will be the raw data that will be used later in the project.

2) We plan to recruit 30-50 people to use as initial cohort for testing our DataAggregator tool. Ideally, at least a good portion of these people would be connected somehow; for instance, maybe they live on the same apartment building, or work at the same company.

3) The final stage is really only the beginning of the "real project" in the sense that we plan to scale the whole study up to 10,000 people or more over the next decade. In order to do that, we would like to create analysis and visualization tools that will enable us to study the behavior of participants. One of our major goals is to use this knowledge to develop data-driven agent-based models that are based on realistic assumptions. Essentially, we would like to create agents that can be used as "living" beings in a city and which we can use for studying the behavior of humans as the environment changes.

Period of Performance

Total duration of the work defined as Phase I: 24 months

Anticipated project start - June 1st, 2013.

Preliminary project timeline:

- Sept 2013 – Define CUSP QC Project Team; initial CUSP QC workshop held
- Oct 2013 – Initial project site visits and initial meetings with Related personnel
- Nov 2013 – Oct 2014 – Define components of QC, develop preliminary QC design manual; define priority areas for Related and identify 3 priority projects; develop DataAggregator tool and launch pilot project; develop UrbanGIS capability
- Nov 2014 – Aug 2015 – Develop implementation strategy for 1-2 priority projects; develop long-term QC research and deployment plan and finalize Phase II partnership agreement between Related and CUSP, and other partners as possible; design parameterized modeling system

SECTION IV – External Partners and Mobilizing the Community

The Related Companies has agreed – in principle – to allow the Hudson Yards site to be the first deployment of the Quantified Community. A formal agreement is currently being finalized.

CUSP faculty members have research strengths in a range of disciplines relevant to study of a QC, from physical technologies and infrastructure, to data science and informatics, to the social sciences ("from sensors to sociologists"). In addition, the Marron Institute on Cities and the Urban Environment would be the ideal organization to bring together and coordinate the engagement of NYU's broader social science and professional faculty to engage in research projects using the QC platform. Specifically, the mission and partners of CUSP align precisely with both the scientific goals of a QC and the ability to implement such a substantial project in real-time. The CUSP Partners bring equipment and expertise that could be used to instrument a QC, ensure its ongoing operation, and assist in data collection and analysis. In addition, the city agencies would have a keen interest in the types of information collected from a QC and the ability to test new policies with immediate feedback loops. It is important to note that the MTA (a CUSP Partner) owns the land on which the Hudson Yards project will be built.

Cisco Systems, Inc. has expressed strong interest in the project, and is currently working with the CUSP team to evaluate and develop the framework for the deployment of the QC. This interest is being led by Sateesh Adepalli, Director of Advanced Architecture, Research and Innovation at Cisco, who is helping to co-convene a research workshop at CUSP in June with PI Constantine Kontokosta. This workshop will bring together key stakeholders from CUSP Partners, potential industry partners, and academic experts to begin the process of designing and mapping the structure of the QC. Additional partners/collaborators will be identified and, when possible secured during the initial phase of the QC project. These partners will provide technical assistance and physical equipment (sensors, control systems, software, etc.) to support the full deployment of the QC project.

Several non-profit organizations and foundations will also be engaged in the initial phase. The World Resources Institute has already expressed interest in the project, as have several other foundations, including Sloan and Rockefeller. Non-profit organizations, including national organizations such as the U.S. Green Building Council, have also expressed interest. Local organizations and community support will be important to the project over the long-term, and these groups will be identified and engaged as appropriate. However, it should be noted that if the project moves forward, as expected, at the Related Hudson Yards site, the single entity ownership and control of the project allows us to move quickly from concept to implementation.

It should be noted, and emphasized, that the QC project is not reliant on Related and the Hudson Yards development site. We have been in conversation with several key local community organizations in Downtown Brooklyn, and all have expressed interest in the QC project being implemented in that neighborhood. These groups include the Downtown Brooklyn Partnership, the Metrotech Business Improvement District, and Brooklyn Navy Yard. In addition, CUSP Partners include thirteen city agencies and the MTA and Port Authority, which have expressed – and signed an MOU – to support CUSP research through access to facilities and data. These relationships would give CUSP a unique ability to utilize publicly-owned facilities for sensor deployments and other physical equipment installations.

APPENDIX

i) MANAGEMENT AND STAFFING PLAN

Constantine Kontokosta will oversee the development of the QC project design and deployment strategy, and will lead the implementation of the QC project. Kontokosta has led significant research projects and complex organizations. As Deputy Director of CUSP, he has helped to shape the strategic direction of the Center; designed, launched, and operationalized its educational programs; and led research initiatives in building informatics and energy efficiency. As Founding Director of the Center for the Sustainable Built Environment at the Schack Institute for Real Estate, Kontokosta launched and expanded the research center focused on urban sustainability issues. The Center has grown to include a team of researchers, staff, and a faculty committee, a student/alumni committee, and an industry advisory board. Kontokosta was also part of the successful team to secure funding for the NYC Urban Technology and Innovation Center (UTIC). The UTIC was designed to provide research, education, and outreach to support green building technology testing, demonstration, and commercialization. Kontokosta also was co-lead for the Economics, Behavior, and Policy component of the New York team response, led by Syracuse University, to the U.S. Department of Energy $125 Million Energy Efficient Buildings Hub Funding Opportunity. In the private sector, Kontokosta has led the planning, design, development, and operations of more than $100M in real estate projects through a company he founded.

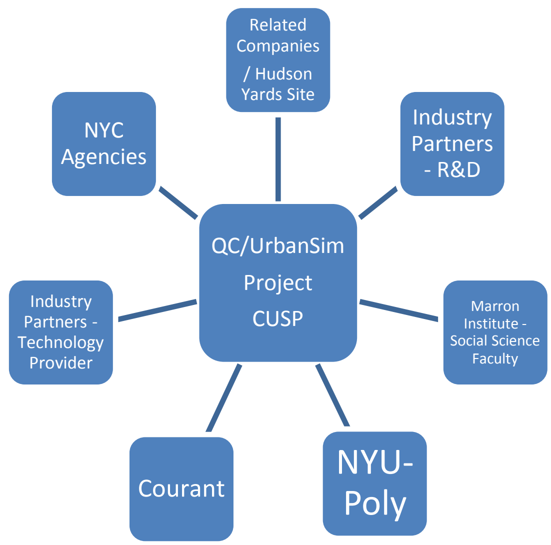
Claudio T. Silva is Head of Disciplines of CUSP, Professor of Computer Science and Engineering at NYU Poly, and affiliate faculty at Courant and the Center for Data Science. He has held research positions at industrial and government labs including AT&T Labs-Research, IBM Research, Sandia National Laboratory and Lawrence Livermore National Laboratory. He has participated on several national and international research projects with major software components, including VisTrails and UV-CDAT. He will play a leading role on the visualization, data management, and software development parts of the project.

Denis Zorin is a Professor of Computer Science and Mathematics at the Courant Institute of Mathematical Sciences at New York University (NYU). He is an associate editor of ACM Transactions on Graphics, the leading journal in the field. Denis was a program committee co-chair of the Symposium on Geometry Processing and program committee member of numerous conferences including all leading conferences in Computer Graphics. His former students and postdocs currently hold faculty positions at a number of universities, including Stanford, Columbia, University of Toronto, University of Texas at Austin and University of Michigan. His work has won a number of best paper awards; he currently holds five patents. Denis's primary interests span the domains of geometric modeling, geometry processing and scientific computing. His main contributions are in the theory and practical algorithms for subdivision surfaces, surface deformation and mapping and efficient computational methods for integral equations. He has won the ACM Gordon Bell Prize, several IBM Partnership Awards , NSF Career Award and Sloan Foundation Fellowship. On the project, he will work on geometry processing and simulation tools.

Management Plan
The management structure for the project will consist of the core QC/SimNYC project team, based at CUSP, with faculty and students from NYU-Poly, Courant, and multiple social science and professional fields, organized and coordinated through the Marron Institute. Industry partners will play an important role. CUSP Partners may be engaged, although the QC/SimNYC project may have additional partners distinct from those in CUSP. MOUs will be signed with Industry partners to support research and development, technology and equipment installation and deployment, and data processing software and hardware contributions. New York City agencies will be engaged to provide additional, correlative

data and to support collaboration and study of the city-wide application of interventions proposed and deployed at the QC site. Relevant agencies and offices include the Department of Building, Department of City Planning, Department of Environmental Protection, Department of Sanitation, and the Mayor's Office of Long-Term Planning and Sustainability. The relationships between the various stakeholders are shown in **Figure 4**.

Figure 4: Structure of the QC/UrbanSim Project at CUSP



ii) BIOGRAPHICAL INFORMATION

CONSTANTINE E. KONTOKOSTA, PhD, PE

NYU Center for Urban Science and Progress
1 Metrotech Center, Room 1941
New York, NY 11201
347-409-2880
ckontokosta@nyu.edu

Professional Preparation

University of Pennsylvania	Systems Engineering – Civil	BSE	1998
New York University	Real Estate Finance and Economics	MS	2003
Columbia University	Urban Planning	MS	2005
Columbia University	Urban Planning	MPhil	2008
Columbia University	Urban Planning	PhD	2011

Academic Appointments

2012-Present	Inaugural Deputy Director, NYU Center for Urban Science and Progress
2009-Present	Founding Director, NYU Center for the Sustainable Built Environment
2012-Present	Adjunct Associate Professor of Urban Planning, NYU Wagner
2011-2012	Clinical Associate Professor, NYU Schack Institute of Real Estate
2011-2012	Director of Policy and Finance, NYC Urban Technology Innovation Center
2008-2011	Clinical Assistant Professor, NYU Schack Institute of Real Estate
2007-2008	Adjunct Assistant Professor, NYU Schack Institute of Real Estate
2005-2008	Teaching Fellow, Columbia University

Five Relevant Publications

Kontokosta, Constantine E. Forthcoming. *Big Data and Sustainable Property Markets: Decision-Making in the Age of Informatics*. London: Routledge.

Kontokosta, Constantine E. 2013. "Information Disclosure and Decision Models: The Case of Building Energy Performance," *Annals of the New York Academy of Sciences*.

Kontokosta, Constantine E. 2013. "Mixed-Income Housing and Neighborhood Integration: Evidence from Inclusionary Zoning Programs," *Journal of Urban Affairs*.

Kontokosta, Constantine E. Forthcoming. "Tall Buildings and Urban Expansion: Tracing the History of Zoning in the United States," *ASCE Journal of Leadership and Management in Engineering*.

Kontokosta, Constantine E. 2012. "The Price of Victory: The Impacts of the Olympic Games on Residential Real Estate Markets," *Urban Studies* 49: 961-978.

Five Other Significant Publications

Kontokosta, Constantine E. 2012. *Local Law 84 Energy Benchmarking Data*. Report to the New York City's Mayor's Office of Long-Term Planning and Sustainability.

Kontokosta, Constantine E. 2012. "Market Transformation through Information: The Role of Building Energy Performance Data in Reducing Global Greenhouse Gas Emissions," *UN Global Forum on Human Settlements: World Best Practices*, 12: 93-98.

Kontokosta, Constantine E. 2012. "Predicting Building Energy Efficiency Using New York City Benchmarking Data," *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings*.

Kontokosta, Constantine E. 2011. "Greening the Regulatory Landscape: The Spatial and Temporal Diffusion of Green Building Policies in U.S. Cities," *Journal of Sustainable Real Estate* 3: 68-90.

Kontokosta, Constantine E. *National Report on Buildings & Climate Change: Energy & GHG Baseline and Reduction Potential for the U.S. Building Sector*. Paris: United Nations Environment Programme, forthcoming 2013.

Honors and Awards

2012	Elected to Fellow of the Royal Institution of Chartered Surveyors
2012	University Research Challenge Fund, New York University
2012	Research Grant, Real Estate Research Institute
2012	Teaching Excellence Award, New York University (SCPS)
2012	Green Grant, Sustainability Task Force, New York University
2011	Research Grant, Office of Sustainability, New York University
2011-2013	Research Grant and Academic Partner, United Nations Environment Programme
2010	Outstanding Service Award, New York University (SCPS)
2010, 2012	Climate, Buildings, and Behavior Scholarship, Garrison Institute
2009-2014	Fulbright Senior Specialist, J. William Fulbright Foreign Scholarship Board/ CEIS
2009-2010	Green Grant, Sustainability Task Force, New York University
2009-2010	C. Lowell Harriss Dissertation Fellowship, Lincoln Institute of Land Policy
2009-2010	Dissertation Research Grant, Graduate School of Arts and Sciences, Columbia University
2008-2010	Doctoral Dissertation Research Grant, US Dept. of Housing and Urban Development
2005-2010	University Fellowship (5-year award), Columbia University
2007	Graduate Student Scholarship, American Society of Civil Engineers
2006	New Scholar Workshop, Journal of Planning Education and Research
2005	Charles Abrams Award for Best Thesis, GSAPP, Columbia University
2001-2003	Dean’s Fellowship (multi-year, merit-based award), New York University

Synergistic Activities

- Founding Director of the Center for the Sustainable Built Environment and created faculty committee consisting of faculty from over ten schools/programs across NYU; developed NYU Schack Institute M.S. degree Sustainable Development concentration curriculum; served on the NYU Abu Dhabi Urban Systems Engineering Curriculum Committee and Faculty Search Committee.
- Member of Executive Team of the NYC Urban Technology Innovation Center, together with Kurt Becker of NYU-Poly. Responsible for Working Groups related to Building Energy Efficiency Policy and Finance.
- Appointed member of the New York City Council’s Municipal Entrepreneurial Testing System Advisory Committee, Mayor Bloomberg’s Local Law 87 Task Force, and the New York City 80x50 long-term carbon reduction plan.
- Member of the Board of the United Nations Environment Programme Sustainable Buildings and Climate Initiative; member of the Board of the Royal Institution of Chartered Surveyors; founding member of the Governance Team of the Urban Systems Collaborative.
- Chair of the three annual Conferences on Sustainable Real Estate, two Urban Systems Symposiums, and the Hofstra-Columbia-NYU Regional Sustainability Conference.

Collaborators: Franz Fuerst (Cambridge University), Tom Geurts (George Washington University), Pat McAllister (University of Reading); Mohammad Karamouz (NYU-Poly); Claudio Silva (NYU-Poly); Nicholas de Monchaux (UC Berkeley)

Research Interests: Real estate finance and economics, urban economics, sustainable real estate markets, commercial building energy performance, urban systems and sustainability, urban operational efficiencies, urban infrastructure investment, econometric models, public finance, project finance

NAME Silva, Cláudio T.	POSITION TITLE Professor, Polytechnic Institute of NYU and Head of Disciplines, CUSP
eRA COMMONS USER NAME	

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR	FIELD OF STUDY
Federal University of Ceará , Brazil	B.S.	1990	Mathematics
State University of New York at Stony Brook	M.S.	1993	Applied Mathematics
State University of New York at Stony Brook	Ph.D.	1996	Computer Science
State University of New York at Stony Brook	Postdoc	1997	Applied Mathematics

A. Personal Statement

Silva is an expert on the geometric computing and data analysis and visualization of Big Data. He is also interested in high-performance computing and the use of GPU clusters. This project will generate large amounts of data of from various sources for analysis. Furthermore, it will require novel computation techniques. Silva will work closely with the rest of the team to design and develop the tools and techniques for data management, analysis, and visualization for the project.

B. Positions and Honors

Professional Positions

1997-1999 Research Staff Member, IBM T. J. Watson Research Center
1998-2000 Adjunct Assistant Professor, State University of New York at Stony Brook
1999-2002 Senior MTS, AT&T Labs-Research
2002 Principal MTS, AT&T Labs-Research
2003 Faculty Scholar, Lawrence Livermore National Laboratory
2002-2006 Associate Professor, OGI School of Science & Engineering at OHSU
2003-2010 Associate Professor, University of Utah
2010-2011 Professor, University of Utah
2011-present Professor, Polytechnic Institute of New York University
2012-present Head of Disciplines, NYU Center for Urban Science and Progress

Other Experience and Professional Memberships

2002 DIMACS Workshop on Visualization and Data Mining
2002-2006 IEEE Transactions on Visualization and Computer Graphics Editorial Board
2003 DIMACS Implementation Challenge on Surface Reconstruction
2005-2006 Papers co-chair, IEEE Visualization
2006-present IEEE Computing in Science & Engineering Editorial Board
2008-present Computer & Graphics Editorial Board
2010 General co-chair, IEEE Visualization
2010-present Graphical Models Editorial Board
2011-present The Visual Computer Editorial Board
2013 Computer Graphics Forum Editorial Board
2013 Co-chair, IEEE Symposium on Large-Scale Data Analysis and Visualization

Program Committee Member (over 100 conferences, including)

IEEE Visualization; SIGGRAPH; Eurographics; Pacific Graphics; Symposium on Point-Based Graphics; Shape Modelling International; Symposium on Geometry Processing.

Awards

2005-2007 IBM Faculty Award (awarded three times)

2007 Dean’s teaching commendation
2007 Best paper award at IEEE Visualization
2008 Best paper award at IEEE Shape Modeling International
2010 Best paper award at Eurographics EDUCATOR program
2011 Best paper award at ACM Eurographics Symposium on Parallel Graphics and Visualization
2013 IEEE Fellow

C. Selected peer-reviewed publications (selected from over 200 publications and 11 U.S. patents)

1. Morisette J, Jarnevich C, Holcombe T, Talbert C, Ignizio D, Talbert M, **Silva C**, Koop D, Swanson A, and Young N. VisTrails SAHM: visualization and workflow management for species habitat modeling. Ecography, to appear.
2. Santos E, Poco J, Wei Y, Liu S, Cook R, Williams D, and **Silva C**. UV-CDAT: Analyzing Climate Data sets from a User’s Perspective. Computing in Science and Engineering, 2013.
3. Fekete J and **Silva C**. Managing Data for Visual Analytics: Opportunities and Challenges. IEEE Data Eng. Bull, 35(3):27–36, 2012.
4. Freire J and **Silva C**. Making Computations and Publications Reproducible with VisTrails. Computing in Science and Engineering, 14(4):18–25, 2012.
5. Ha L, Prastawa M, Gerig G, Gilmore J, **Silva C** and Joshi S. Efficient Probabilistic and Geometric Anatomical Mapping using Particle Mesh Approximation on GPUs. International Journal of Biomedical Imaging, 2011.
6. Ferreira N, Lins L, Fink D, Kelling S, Wood C, Freire J, and **Silva C**. BirdVis: Visualizing and Understanding Bird Populations. IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVIS 2011), 17(12):2374–2383, 2011.
7. Bauer B, Carr LD, Evertz HG, Feiguin A, Freire J, Fuchs S, Gamper L, Gukelberger J, Gull E, Guertler S, Hehn A, Igarashi R, Isakov SV, Koop D, Ma PN, Mates P, Matsuo H, Parcollet O, Pawlowski G, Picon JD, Pollet L, Santos E, Scarola VW, Schollwck U, **Silva C**, Surer B, Todo S, Trebst S, Troyer M, Wall ML, Werner P, and Wessel S. The ALPS project release 2.0: open source software for strongly correlated systems. Journal of Statistical Mechanics: Theory and Experiment (JSTAT), 2011.
8. Ha L, **Silva C**, Krueger J, Comba J, and Joshi S. Optimal Multi-Image Processing Streaming Framework on Parallel Heterogeneous Systems. 11th Eurographics Workshop on Parallel Graphics and Visualization (EGPGV 2011), 2011. **Best paper award**.
9. Koop D, Santos E, Mates P, Vo HT, Bonnet P, Bauer B, Surer B, Troyer M, Williams DN, Tohline JE, Freire J, and **Silva C**. A Provenance-Based Infrastructure for Creating Executable Papers. Procedia Computer Science, 2011. ICCS 2011. **Grand Challenge Finalist.**
10. Anderson E, Potter K, Matzen L, Shepherd J, Preston G, and **Silva C**. A User Study of Visualization Effectiveness Using EEG and Cognitive Load. Computer Graphics Forum (Proceedings of EuroVis 2011). **Best paper award – 2nd prize.**
11. Vo H, Summa B, Osmari D, Comba J, Pascucci V, and **Silva C**. Streaming-Enabled Parallel Dataflow Architecture for Multicore Systems. Computer Graphics Forum (Proceedings of EuroVis 2010).
13. Daniels J, Anderson EW, Nonato LG, and **Silva C**. Interactive Vector Field Feature Identification. IEEE Transactions on Visualization and Computer Graphics (Proceedings of IEEE Visualization 2010).
14. **Silva C**, Anderson E, Santos E, and Freire J. Using VisTrails and Provenance for Teaching Scientific Visualization. Computer Graphics Forum, 30(1):75–84, 2011.(Presented at EUROGRAPHICS 2010 Educator Program, 2010). **Best paper award.**
15. **Silva C**, Freire J, and Callahan SP. Provenance for Visualization: Reproducibility and Beyond. Computing in Science and Engineering, 9(5):82-89, 2007.
16. Scheidegger CE, Vo HT, Koop D, Freire J, and **Silva C**. Querying and Creating Visualizations by Analogy. IEEE Transactions on Visualization and Computer Graphics, 13(6):1560-1567, 2007. **Best paper award.**

Denis Zorin

Address: Courant Institute of Mathematical Sciences, New York University, 719 Broadway, 12th floor, New York, NY 10003; Tel: (212)998-3405; Fax: (212)995-4122; e-mail: dzorin@mrl.nyu.edu

Education

Moscow Institute of Physics and Technology, Comp. Sci. and Physics, B.S., 1991
Ohio State University, Mathematics, M.S., 1993
California Institute of Technology, Computer Science, M.S., 1995
California Institute of Technology, Computer Science, Ph.D., 1997
Stanford University, Computer Science, Postdoc, 1997-98

Appointments

Professor of Computer Science and Mathematics, New York University, current
Associate Professor, New York University,2003-2009
Assistant Professor, New York University,1998-03

Honors and Awards

Sloan Fellowship, 2000, NSF CAREER Award 2001, IBM Partnership Award, 2001,2002,2004, Gordon Bell Prize 2010.

Related Publications

Incremental flattening. A. Myles, D. Zorin. ACM Transactions on Graphics 31, 6, (2012).
Computing extremal quasiconformal maps. O. Weber, A. Myles, D. Zorin. Proceedings of Symposium on Geometry Processing 2012. Best paper award.

Global parametrization of range image sets. N. Pietroni, M. Tarini, O. Sorkine,D. Zorin. ACM Transactions on Graphics 30, 6, (2011).

Feature-algined T-meshes. A. Myles, N. Pietroni, D. Kovacs, D. Zorin. ACM Transactions on Graphics 29, 3 (2010).

Anisotropic quadrangulation. D. Kovacs, A. Myles, and D. Zorin. Symposium on Solid and Physical Modeling, 137–146, (2010).

Additional Publications

Petascale Direct Numerical Simulation of Blood Flow on 200K Cores and Heterogeneous Architectures. A. Rahimian et al. SC 2010: Proceedings of the 2010 ACM/IEEE conference on Supercomputing, 2010. (Gordon Bell Prize).

Interference aware geometric modeling. D. Harmon, D. Panozzo, O. Sorkine, and D. Zorin. ACM Transactions on Graphics 30, 6, (2011).

Discrete quadratic bending energies. M. Wardetzky, M. Bergou, D. Harmon, D. Zorin, and E. Grinspun. Computer-Aided Geometric Design, 24(8-9):499-518, (2007). (most cited paper award).

A fast algorithm for simulating vesicle flows in three dimensions. S. Veerapaneni, A. Rahimian, G. Biros, and D. Zorin. Journal of Computational Physics, (2011).

Computing discrete shape operators on general meshes, E. Grinspun, Y. Gingold, J. Reisman, D. Zorin. Computer Graphics Forum, Proceedings of Eurographics 2006 (2nd Best Paper award), 25, 3, 547–556, (2006)

Synergetic Activities

A collaboration with IBM Research and Dassault Systemes aims to increase integration between geometric modeling and simulation into future versions of a major CAD system. With M. Wright, L. Greengard and D. Keyes, the PI organizes the activities of the NSF-funded NYU/Columbia research and training group “Numerical Mathematics for Scientfic Computing”. The PI is an Associate editor of ACM Transactions on Graphics, and Graphical Models. Conference committees: SIGGRAPH and Eurographics, SGP, SCA, SMI, SMA 2003 Symposium on Geometry Processing Program Co-Chair, Reviews for Journal of Computational Physics, Applied and Computational Harmonic Analysis, Constructive Approximation, SIAM Journal of Scientific Computing, SIGGRAPH, ACM Transactions on Computer Graphics, IEEE Transactions on Visualization and Computer Graphics, Springer-Verlag, Computational Mathematics, ACM Solid Modeling Symposium, Symposium on Interactive 3D Graphics.

Collaborators and Other Affiliations

Collaborators: Maneesh Agrawala, Berkeley; Fausto Bernardini, IBM T.J. Watson Research Center; Ioana Boier-Martin, IBM T.J. Watson Research Center; Cindy Grimm, Washington University; David Keyes, Columbia University; Adi Levin, Tel-Aviv Unversity, Cadent; Tamara Munzner, UBC; Ken Perlin, New York University; Scott Schaeffer, Texas A&M University; Wim Sweldens, Lucent Technologies; Luiz Velho, IMPA, Brazil; Max Wardetzky, G¨ottingen University; Joe Warren, Rice University.
Graduate and Postdoctoral Advisors: Peter Schr¨oder, (Ph.D. advisor, Caltech), Alan Barr, Caltech, (Ph.D. advisor, Caltech), Pat Hanrahan, (postdoc supervisor, Stanford).
Graduate Students and Postdocs. Postdocs: former: Baoquan Chen (U. of Minnesota), George Biros (U. of Pennsylvannia/Gatech/UT Austin), Eitan Grinspun (Columbia); Denis Guyffier(NASA); Shravan Veerapaneni (Michigan),current: Ashish Myles, David Harmon. Graduate Students: former: Aaron Hertzmann (U. of Toronto), Henning Biermann, Jianbo Peng, Lexing Ying (U. of Texas, Austin) Elif Tosun, Evgueni Parilov, Yotal Gingold (Tel-Aviv U.), Adrian Secord. Current: Eduardo Corona,Denis Kovacs, Julian Panetta, James Zhou, Andrew Szymczak, Libin Liu.

iii) BUDGET

BUDGET	Year 1	Year 2[1]	2-year Total
Personnel			
Faculty Salary (summer - 1 month)	$ 15,000	$ 15,450	$ 30,450
Postdoctoral Fellow	$ 50,000	$ 51,500	$ 101,500
PhD Student	$ 23,500	$ 24,205	$ 47,705
Subtotal	*$ 88,500*	*$ 91,155*	*$ 179,655*
Fringe[2]	$ 24,780	$ 25,979	$ 50,759
Total Personnel	**$ 113,280**	**$ 117,134**	**$ 230,414**
Other Expenses			
Participant Support Costs	$ 10,000	$ -	$ 10,000
For Workshops (3 in total)			
Publication Support Costs	$ 2,000	$ 2,000	$ 4,000
Travel	$ 2,500	$ 2,500	$ 5,000
Total Direct Costs	**$ 125,780**	**$ 119,634**	**$ 249,414**
Notes:			
[1]Cost escalation at 3% for second year			
[2]Fringe calculated at 28% for Year 1 and 28.5% for Year 2			

iv) BUDGET NARRATIVE

Personnel Costs – This budget item accounts for partial summer salary for Dr. Denis Zorin, one (1) full-time Postdoctoral Fellow at CUSP for two years, and support for one (1) PhD student for two years. The Fellow and the PhD student will coordinate the development of the sensor networks, three-dimensional models, and simulation capability for the project. They will also work to coordinate day-to-day operations of the QC deployment and act as liaisons with the Related Hudson Yards design team.

Postdoctoral Fellow – This Fellow will be recruited into CUSP for the two-year initial grant period. The Fellow will have expertise in areas in relating to sensor networks, data collection and integration, and additional fields as appropriate.

PhD Student – Funding (stipend) for a PhD student enrolled in a relevant program at NYU-Poly, but based in CUSP with the QC/UrbanSim project team.

Other Direct Costs

Participant Support Costs (Workshops) – a series of three (3) workshops will be held at CUSP to bring together key members of the NYU and CUSP Partner faculty, industry partners, and agency partners, together with the Related Hudson Yards design team, to develop the deployment and implementation strategy for the QC/UrbanSim project. The first will cover the QC physical design elements of sensor installation and deployment; the second will explore the use of Building Information Modeling (BIM) and other modeling techniques; and the final workshop will define QC data management and simulation techniques.

Costs associated with the workshops include honoraria and travel reimbursement for invited participants.

Publication Support Costs – Estimated cost for printing associated with QC deployment plans.

Travel – Cost of travel for QC/UrbanSim project team between Brooklyn and Hudson Yards Site.