Preview of Award 1027752 - Annual Project Report

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1027752
Project Title:	CDI-Type I: Modeling and Predicting State-Topology Coevolution of Complex Adaptive Networks
PD/PI Name:	Hiroki Sayama, Principal Investigator
Submitting Official (if other than PD\PI):	Hiroki Sayama Principal Investigator
Submission Date:	09/29/2013
Recipient Organization:	SUNY at Binghamton
Project/Grant Period:	10/01/2010 - 09/30/2014
Reporting Period:	10/01/2012 - 09/30/2013
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Hiroki Sayama

---

Accomplishments

* What are the major goals of the project?

The rapidly growing complex network science has presented novel approaches to complex systems modeling that were not fully foreseen even in a decade ago. It addresses the self-organization of complex network structure and its implications for system behavior, which holds significant cross-disciplinary relevance to many fields of natural and social sciences, particularly in today's highly networked social/political/economical circumstances.

Interestingly, complex network science has traditionally addressed either "dynamics on networks" (state transition on a network with a fixed topology) or "dynamics of networks" (topological transformation of a network with no dynamic state changes) almost separately. In many real-world complex biological and social networks, however, these two dynamics interact with each other and coevolve over the same time scales. Modeling and predicting state-topology coevolution is now recognized as one of the most significant challenges in complex network science.

The goals of this project are to establish a generalized modeling framework that can effectively describe state-topology coevolution of complex adaptive networks and to develop computational methods for automatic discovery of dynamical rules that best capture both state transition and topological transformation in empirical data. To achieve these goals, graph rewriting systems are used as a means of unified representation of state transition and topological transformation. Network evolution is formulated in two parts, extraction and replacement of subnetworks. For each part, algorithms for automatic rule discovery are explored and developed. Their effectiveness is evaluated through application to real-world network data.

This project will produce a novel theoretical framework and a computational toolkit that will transform the ways of studying the dynamics on and of complex networks.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: We designed and developed PyGNA, a Generative Network Automata (GNA)-based modeling and analysis framework using Python and the NetworkX module. The development is being done using SourceForge.net, a widely used open-source software development website, where all source codes are publicly available for free (http://gnaframework.sourceforge.net/).

The current version (ver. 0.7) of PyGNA has the following capabilities:

(a) Input/output interface of network evolution data. PyGNA can read network evolution data from a file in a graph ML format. Graph ML is an XML-based graph mark-up language that can represent multiple graphs in a single file, which we adopted as a general data format to represent time series of networks. PyGNA can also output network time series into a graph ML file.

(b) Identification of network rewriting events and compression of network evolution data. PyGNA can scan a given graph ML file and sequentially detect differences between two consecutive snapshots of networks, and then utilize this information to compress the network evolution data. When the network differences are identified, several statistical measurements associated with the differences are also recorded.

(c) Automatic discovery of subgraph extraction rules. Given multiple candidate models of subgraph extraction mechanisms, PyGNA can calculate the likelihood of each mechanism based on the compressed network evolution data. The calculated likelihood values will be used to select the most plausible extraction mechanism with the largest likelihood value. The most recent version of PyGNA can calculate the likelihood of network rewriting events at a motif level, not just at individual node levels.

(d) Automatic discovery of subgraph rewriting rules and reconstruction of network evolution. PyGNA can use the collection of network changes generated in (b) above as a set of subgraph rewriting rules and perform network rewritings so as to reconstruct network evolutionary processes from an initial configuration (i.e., simulation of network evolution).

(e) Simple scripting language for model specification. This PyGNA-specific scripting language is developed so that the users can write their own likelihood calculation models. Its syntax is loosely based on Python. PyGNA uses such user-defined likelihood functions for model evaluations.

(f) Quantitative evaluation and comparison of multiple models for the extraction mechanism using logarithmic sums of subgraph extraction probabilities.

(g) Online tutorial written as an executable Python code.

Specific Objectives: [Testing algorithms with abstract network models]

We conducted experiments applying PyGNA to data generated by abstract adaptive network models, in order to test if it could correctly identify the actual network generation mechanisms used to reproduce the input data. The following four abstract network models were used as inputs to PyGNA:

(a) Barabasi-Albert network, grown using the standard degree-based preferential attachment method.
(b) "Degree-state" network, grown by degree-based preferential attachment applied only to the subset of nodes that have a particular state. Each newly added node is assigned with a randomly selected state.
(c) "State-based" network, grown by random attachment only to nodes that have a

particular state. Again, each newly added node is assigned with a randomly selected state.
(d) "Forest fire" network, generated by the method proposed in the literature.

We quantified the accuracy of the reconstructed network models by using several measurements, including the resulting degree distributions and the probability distributions of extracted subgraphs. For the latter, we counted how many times each of the different kinds of subgraphs was selected for graph rewriting events in the original input data and the reconstructed network simulation results. The Bhattacharyya distance was then computed between the two distributions.

[Collecting real-world network data]

Real-world network evolution data are necessary for evaluation of our algorithms. We developed an original web search engine based method for collecting approximated historical data of temporally changing social adaptive networks. In our method, a search query string is combined with additional keywords that specify the inclusion/exclusion of specific years to limit the search results to a particular time point. Using the proposed method, we reconstructed the temporal evolution of a social network from 2005 to 2009 of 93 individuals who are important in the US economy as a test case.

We also used this method to reconstruct a network that represents the relatedness between scientists and their peers as well as various research topics. We characterized each individual scientist's most notable research topics (expertise) by measuring a "visibility boost", defined as the increase of the scientist's visibility resulting from focusing on a particular research topic. We analyzed the correlation between scientists' expertise and their interdisciplinary nature. The interdisciplinarity of a scientist was characterized in two different ways: (a) diversity in their expertise (i.e., how many research topics they are associated with), and (b) their betweenness centrality in the scientists' network (i.e., how much they connect multiple scientific communities). While this research did not consider the dynamical nature of the network, it did demonstrate the effectiveness of our data collection method.

Furthermore, we have been working with our collaborators to collect other types of real-world adaptive network data (Dr. Zhirong Bao at Memorial Sloan-Kettering Cancer Center for the data of spatial cellular network evolution over the embryogenesis of C. elegans, and Dr. Junichi Yamanoi at Chuo University for the data of social/business network evolution in Japanese colleges and industries).

[Expanding domains of application]

(a) Adaptive network models of social network evolution. We developed an agent-based model of idea-exchanging social networks to investigate the relationship between individual behavior of agents and their contribution to collective idea generation. Our individual agents divide their time into three distinct actions: thinking about and reconciling one's own ideas, disseminating ideas to others, and listening to ideas from one's peers. Each individual is host to a local population of ideas, some of which are fixed, while others can be replaced as a result of social interaction. Individuals evaluate ideas based on their local idea population, and these evaluations are used to update the (directed) link weights whenever ideas are exchanged. We implemented a parallel simulation platform based on a server-client architecture for this experiment. Using this model and its simulation platform, we conducted exhaustive parameter sweep experiments, calculating the distribution of network centrality of agents and other measurements of their idea contribution.

(b) Adaptive network models of corporate merger. In collaboration with Dr. Junichi Yamanoi at Chuo University, Japan, we developed an adaptive network model of cultural integration in merging firms, represented as a network initially made of two communities. Nodes receive information from their neighbors and update their cultural states, while the link weights also change so that links between nodes with similar/different cultural states are encouraged/discouraged. We investigated the impact of network structures within and between two merging firms on post-merger cultural integration and organizational dysfunctions---individual turnover, interpersonal conflict and organizational communication ineffectiveness---that arise from insufficient cultural integration.

(c) Adaptive network based models of collective behavior of swarms. In collaboration with Dr. Thilo Gross, we developed an adaptive network-based analytical model that represents interaction networks of marching locust swarms that may switch the direction of motion between left and right. Dr. Gross's recent work considered phase transitions in a homogeneous swarm. We extended their model to heterogeneous swarms made of multiple types. To facilitate analytical work, we developed a computer program that automatically generates all the network rewriting rules from a smaller set of model assumptions, and also a set of dynamical equations that describe dynamical change of network motif densities using a technique called moment closure. We applied this software to analyze the dynamics of collective movements of heterogeneous swarms made of two types.

(d) Incorporation of GNA into network models of joint technological systems. We established a research contract with Defence Research and Development Canada Centre for Operational Research and Analysis (DRDC-CORA) to develop GNA-based computer simulation models and analysis tools of the behavior of dynamical operational networks made of heterogeneous specialized agents, each working in distinct environmental domains. A target problem is the SAR (Search and Rescue) operational network for the Canadian Arctic. This project was the first instance of real-world applications of our GNA framework used in non-academic domains. In collaboration with Dr. Irene Pestov at DRDC-CORA, we developed OpNetSim, an adaptive network-based computer simulation model of the behavior of dynamical operational networks made of heterogeneous specialized agents, each working in distinct environmental domains. The final simulator software and its user's manual were produced and delivered to DRDC-CORA as specified in our contract.

(e) Adaptive network models of global state drift in social diffusion. We developed an adaptive-network model of social diffusion where node degrees are artificially correlated with node states through adaptive link replacement. In this model, node states diffuse through links in the form of non-conserved social diffusion (i.e., a node's state tends to approach the average of its neighbors' states). In addition, a small number of links are randomly chosen and removed from the network in each iteration and replaced by the same number of new links between nodes that are selected preferentially based on their states. We applied this mathematical model to study the effects of such adaptive rewriting on the global drift of average states, especially in the context of education, where nodes, states and links represent students, their grades and their friendships.

Significant Results: [Testing algorithms with abstract network models]

To test the algorithms we developed, we compared the reconstructed networks produced by PyGNA to the original input networks generated according to the aforementioned four network growth mechanisms.

In the initial testing experiments, both input and reconstructed networks had visually similar structures for the Barabasi-Albert (a), degree-state (b) and state-based (c) networks. For the forest fire network (d), however, PyGNA failed to capture the unique topological characteristics of the original input network, because of the complexity in the original network generation method. The accuracy of the reconstructed network models was also characterized by measuring the Bhattacharyya distance (BD) of probability distributions of extracted subgraphs between original and reconstructed networks. The BD was low for (a) and (c), while it was high for (b) and (d). We learned from these results that the initial algorithm in PyGNA was effective for certain types of networks while still limited for the analysis of others, especially those that involve pure randomness and/or mesoscopic topological structures such as motifs.

To address these problems, we implemented major improvements in the algorithms of PyGNA. One substantial extension made to the extraction mechanism detection algorithm (which was realized through intensive discussions with Dr. Gross during our stay at the University of Bristol) was to use a motif-based likelihood calculation, instead of a node-based one that was originally adopted. This improvement led to a significant increase in the performance of PyGNA's automated model building abilities. The reconstructed networks looked much closer to the original input networks than before, and both the extracted subgraph distributions and the cumulative degree distributions matched more closely between the input and reconstructed networks.

[Collecting real-world network data]

Using our web search engine-based data collection method, we reconstructed the temporal evolution of a social network from 2005 to 2009 of 93 individuals who are important in the US economy. We measured centralities of those individuals for every year and found several illustrative cases where the temporal change of centrality of an individual correctly captured the actual events that are related to him/her over this time period. These results indicate the effectiveness of the proposed data collection method.

We also used our data collection method to reconstruct a network that represents the relatedness between scientists and their peers as well as various research topics. We found that researchers who had high "visibility boosts" by the same research topic tended to be close to each other in their network. We calculated correlations between visibility boosts by research topics and researchers' interdisciplinarity at the individual level (diversity of topics related to the researcher) and at the social level (his/her centrality in the researchers' network). We found that visibility boosts by certain research topics were positively correlated with researchers' individual-level interdisciplinarity despite their negative correlations with the general popularity of researchers. It was also found that visibility boosts by network-related topics had positive correlations with researchers' social-level interdisciplinarity. Research topics' correlations with researchers' individual- and social-level interdisciplinarities were found to be nearly independent from each other. These findings suggest that the notion of "interdisciplinarity" of a researcher should be understood as a multi-dimensional concept that should be evaluated using multiple assessment means.

[Expanding domains of application]

(a) Adaptive network models of social network evolution. Results of computer simulation showed that the relationship between individual agent behavior and several dependent variables, including network centrality, ideational contribution, and ideational interaction strongly depended on a simulation parameter representing the agent's ability to generalize ideas. A transition point for this parameter was found such that centrality relationships observed on either side of the transition point are inverses of each other. The same transition behaviors were also found for other measurements, such as the agent's contributions to idea generation and idea dissemination.

(b) Adaptive network models of corporate merger. Using an agent-based model, we investigated the impact of network structures within and between two merging firms on post-merger cultural integration and organizational dysfunctions---individual turnover, interpersonal conflict and organizational communication ineffectiveness---that arise from insufficient cultural integration. The simulation results demonstrated that the highest level of cultural integration is achieved when social ties are more centralized within each merging firm and the social ties between the merging firms are less concentrated on central individuals. Additionally, the results showed that within-firm and between-firm network structures significantly affect individual turnover, interpersonal conflict and organizational communication ineffectiveness, and that these three outcome measurements do not vary in tandem.

(c) Adaptive network based models of collective behavior of swarms. We applied our automatic equation generating software to analyze the dynamics of collective movements of heterogeneous swarms made of two types analytically. We found that the difference in behavioral traits between the two types tended to increase the local homogeneity within the population. No clear phase transition was detected, however.

(d) Incorporation of GNA into network models of joint technological systems. We analyzed and modeled a real SAR incident in the Arctic that occurred in December 2008. We examined the actual log of inter-agent communications during this SAR incident, and manually reconstructed the rewriting rules that drove the operational network formation. OpNetSim, our simulator software, was then used to simulate the temporal development of the operational network under several hypothetical scenarios. Since the simulation algorithm involves stochasticity, the topology of the simulated network does not exactly match the actual one, but the general trend of increasing agent heterogeneity and concentration on the Search Master node were correctly represented in this model.

(e) Adaptive network models of global state drift in social diffusion. We conducted systematic simulations with the link replacement probability and the strength of preferential replacement varied. Results showed that the adaptive link replacement with positive preferential selection caused positive drift of average node states via social diffusion over time. The proposed approach may be practically implementable in educational settings by, e.g., allowing higher-achieving students to participate in more extracurricular activities.

Key outcomes or Other achievements:

[Educational Outreach]

We developed NetSci High: High School Student Research on Network Science, an educational outreach program organized and run in close collaboration with Dr. Stephen Uzzo, Ms. Tara Chudoba and Ms. Catherine Cramer at the New York Hall of Science. This program aims to infuse network science, an emerging interdisciplinary field of study on complex networks, into K-12 education by connecting high school students and teachers to university research labs and letting them work on current network science research for several months, culminating in a poster presentation at NetSci conferences.

In early Fall 2010, we organized initial teachers' workshops at three locations (New York City, Boston, and Binghamton) to recruit high school science/math teachers and students to this program. The PI attended the New York City workshop and also hosted the Binghamton workshop. As a result, seven student teams and their teachers participated in the program during 2010-2011 and worked with their local research laboratories. In Binghamton, the PI, Bush and Akaishi collaboratively supervised two student teams (seven female students) in Maine-Endwell high school in Endwell, NY, in close collaboration with Mrs. Julie Gallagher, Assistant Principal of the school.

Each of the seven participating teams worked on its own research project in network science and submitted a poster electronically by mid-April, 2011. The submissions were then reviewed by a scientific committee made of leading network scientists, who selected two winning posters. As a result, four high school students and their teachers (three of them, each representing a different school) traveled to Hungary, Budapest, in June 2011, to participate in the 2011 International Conference on Network Science (NetSci 2011) and present their work there in person. The travel costs were covered by this grant. All of the seven posters were printed and put up at NetSci 2011. Unfortunately none of the Binghamton student teams were selected as winners. The PI later arranged another poster session at the Eighth International Conference on Complex Systems (ICCS 2011) in Boston, MA, for which he served as a Program Chair. Some of the students who could not go to NetSci 2011 were able to come and present their work at ICCS 2011 on their own. At each poster session, the audience was asked to fill in a comment sheet to give encouragement and feedback to the students and teachers who participated in this program.

The second year of the NetSci High program was run as scholarships offered to participating high school student teams. Two student teams participated from the Binghamton area. Due to the shortage of time for program preparation, we could not recruit teams from other areas. The PI supervised one team from Maine-Endwell High School, while another professor in Computer Science at Binghamton University supervised another team from Vestal High School. Those teams were offered a scholarship to attend the NetSci 2012 conference in Evanston, IL, on June 18-22, 2012, and presented their posters to international audience. For the second year of the program, we also received a corporate donation from BAE Systems. The Maine-Endwell team's research was later put into a journal article and published in PLOS ONE in 2013. This paper attracted a lot of media attention internationally.

We also organized a satellite symposium on education (NetSciEd) at the NetSci 2012 conference. This symposium aimed to address how network science will transform STEM education in the coming years, in anticipation of preparing the next generation of network scientists, as well as addressing the urgent needs in improving STEM education overall. Topics discussed at this event included:
* Network Science in K-16 Practice and Policy
* Network Science in Informal Education
* New Directions in Learning Science
* Developing Metrics for Effective Educational Collaboration Networks

Nine presentations were made by invited speakers who work on the intersection between network science and education. All the presentations are made available publicly on the symposium website. The PI also gave a presentation on his own experience supervising high school students' research projects on networks. At the end of the symposium, a highly active panel discussion was held to determine directions in support of research and practice in the use of network science to improve education.

After the initial two-year pilot period, NetSci High expanded further as the NSF ITEST project "Network Science for the Next Generation", led by Boston University and the New York Hall of Science. The PI continued to participate in the ITEST project as a consultant.

For the third year of the NetSci High program, the PI supervised one student team from Vestal High School. They participated in a NetSci High summer workshop held at Boston University in the summer of 2012 to learn basics of network science and relevant research methods. They worked with the PI throughout the academic year and prepared a poster by June 2013. Their poster was presented at the NetSci 2013 conference in Copenhagen, Denmark. They also participated in the NetSci High research conference held again at Boston University in the summer of 2013, and presented their project to the audience, including the next cohort of NetSci High participants.

We also organized the second satellite symposium on education (NetSciEd2) at the NetSci 2013 conference. This symposium was organized and hosted in collaboration with the New York Hall of Science. Eleven presentations were made by invited speakers who work on the intersection between network science and education. The PI was a co-organizer of this event.

For the fourth year of the NetSci High program, the PI is currently supervising two student teams from Vestal High School.

Moreover, the PI organized a regional workshop on K-12 Science Education Outreach at Binghamton University on October 19, 2012, together with Dr. Zhongfei (Mark) Zhang in Computer Science. This workshop aimed to bring all the parties involved in educational outreach activities at Binghamton University and local schools to discuss their approaches, exchange ideas, and brainstorm future developments as a community for engaging the school kids into scientific activities, to serve the ultimate goal of improving and enhancing the K-12 education in this nation in general and in the local community specifically. More than two dozens of panelists participated and had very active and fruitful discussions about educational outreach. For more details, see the workshop website.

* What opportunities for training and professional development has the project provided?

This project provided a number of training and professional development opportunities to all involved, including (1) interdisciplinary graduate training for two graduate research assistants, (2) international research collaboration experience for the PI and the graduate students, and research experience for undergraduate students involved in the project. For more details, please see the "Impact" section.

* How have the results been disseminated to communities of interest?

The results of the project have been disseminated through the project websites, publications of journal articles and conference proceedings papers, presentations at conferences and seminars, and other public media channels. Some notable publications include:

Hiroki Sayama, Irene Pestov, Jeffrey Schmidt, Benjamin James Bush, Chun Wong, Junichi Yamanoi, and Thilo Gross, Modeling complex systems with adaptive networks, Computers and Mathematics with Applications, 65, 1645-1664,

2013.
- This paper summarizes the overview of the project, describing computational algorithms we developed and applications to social and technological network modeling. It was published this year yet has been cited five times already.

Deanna Blansky, Christina Kavanaugh, Cara Boothroyd, Brianna Benson, Julie Gallagher, John Endress, and Hiroki Sayama, Spread of academic success in a high school social network, PLOS ONE, 8(2), e55944, 2013.
- This paper is an outcome of the NetSci High educational outreach, summarizing the results of the research project by the Maine-Endwell high school students and the PI. This paper has received a tremendous amount of attention from national as well as international media. It has acquired more than ten thousand views in six months since its publication.

Also notable are the following two presentation awards that one of the graduate students (Jeffrey Schmidt) and the PI won:

* Best Student Paper Award: Jeffrey Schmidt at IEEE ALIFE 2013

* Best Presentation Award: Hiroki Sayama at IPSJ SIG Mathematical Modelling and Problem Solving in 2010

See the "Products" section for more details.

* What do you plan to do during the next reporting period to accomplish the goals?

In the final year of the project, we will focus on (1) the applications of PyGNA to the analysis of several real-world temporal network data, and (2) further disseminations of the project outcomes through publications of more journal articles. The two graduate students are also expected to finish their PhD theses by the end of this project.

Products

Journals

Hiroki Sayama, Irene Pestov, Jeffrey Schmidt, Benjamin James Bush, Chun Wong, Junichi Yamanoi, and Thilo Gross (2013). Modeling complex systems with adaptive networks. *Computers and Mathematics with Applications*. 65 1645.

Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Deanna Blansky, Christina Kavanaugh, Cara Boothroyd, Brianna Benson, Julie Gallagher, John Endress, and Hiroki Sayama (2013). Spread of academic success in a high school social network. *PLOS ONE*. 8 (2), e55944.

Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Junichi Yamanoi and Hiroki Sayama (2012). Post-merger cultural integration from a social network perspective: A computational modeling approach. *Computational and Mathematical Organization Theory*. .

Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes

Books

Book Chapters

Thesis/Dissertations

Jeffrey A. Schmidt. *PyGNA: Designing and Evaluating Algorithms for Automated Discovery of Adaptive Network Models Based on Generative Network Automa*. (2012). Binghamton University.

Acknowledgment of Federal Support = Yes

Conference Papers and Presentations

Jeffrey Schmidt and Hiroki Sayama (2013). *Designing and evaluating algorithms for automated discovery of adaptive network models based on Generative Network Automata*. Fourth IEEE Symposium on Artificial Life. Singapore.

Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Hiroki Sayama (2013). *Computational modeling and prediction of adaptive network dynamics*. Uncertainty in Interaction Networks. Bath, UK.

Status = OTHER; Acknowledgement of Federal Support = Yes

Jeffrey Schmidt and Hiroki Sayama (2013). *Automatic discovery of adaptive network dynamics from temporal network data*. NetSci 2013: International School and Conference on Network Science. Copenhagen, Denmark.

Status = OTHER; Acknowledgement of Federal Support = Yes

Hiroki Sayama (2013). *Make geeks popular: An adaptive network approach to induce positive drift of students' grades diffusing in their social network*. NetSci 2013: International School and Conference on Network Science. Copenhagen, Denmark.

Status = OTHER; Acknowledgement of Federal Support = Yes

Dan Seel, Per Andre Stromhaug, Carol Reynolds, Kristie Shirreffs, and Hiroki Sayama (2013). *An analysis of the networks of product creation and trading in the virtual economy of Team Fortress 2*. NetSciEd2: Second NetSci Satellite Symposium on Network Science in Education. Copenhagen, Denmark.

Status = OTHER; Acknowledgement of Federal Support = Yes

Other Publications

Technologies or Techniques
Nothing to report.

Patents
Nothing to report.

Inventions
Nothing to report.

Licenses
Nothing to report.

Websites

Title:	Project website
URL:	http://coco.binghamton.edu/NSF-CDI.html
Description:	Generative Network Automata framework software (PyGNA) on SourceForge.net
Title:	http://gnaframework.sourceforge.net/
URL:	NetSci High website
Description:	https://sites.google.com/a/binghamton.edu/netsci-high-2011-2012/
Title:	NetSciEd Symposium website
URL:	https://sites.google.com/a/binghamton.edu/netscied12/
Description:	NetSciEd2 Symposium website
Title:	https://sites.google.com/a/binghamton.edu/netscied2013/

URL: Workshop on K-12 Science Education Outreach @ BU website

Description: http://bingweb.binghamton.edu/~sayama/K12SEO-BU-workshop.html

Title:

URL:

Description:

Title:

URL:

Description:

Other Products

Product Type: Software or Netware

Description: [Developing PyGNA]

We developed PyGNA --- the Generative Network Automata (GNA) modeling, analysis and simulation framework implemented as a Python module. This framework allows a user to construct adaptive network models based on GNA, either based on the user's own network rewriting rules or rules that are automatically reconstructed from given network evolution data. The framework also allows dynamic simulations of network behavior.

The first public release version of PyGNA (ver. 0.6) was released in September 2012, and the second public release version (ver. 0.7) was released in August 2013. Its source codes and other information are all publicly available from our SourceForge.net site.

Other: Educational aids or Curricula

Product Type: [Course development]

Description: The PI developed a new graduate-level course "BME-523X: Dynamics of Complex Networks", which was approved by the Binghamton University Graduate Studies Committee and officially ran in Spring 2012. See the attached course syllabus for more details. This course provided students with concepts and mathematical/computational tools of network science, for modeling, analyzing and simulating the dynamics of various complex adaptive networks. Python and NetworkX were used for modeling and analysis of complex networks. The GNA framework was also integrated in the course materials. The course was received very positively by the students and has been approved to be a permanent graduate course by the University. Due to schedule conflicts, this course has not been offered since Spring 2012, but some of the course materials are covered in the PI's other course (SSIE 523: Collective Dynamics of Complex Systems) in Spring 2013.

Other: Other

Product Type: We organized the following meetings:

Description: * STCAN 2010: Special Track on State-Topology Coevolution in Adaptive Networks. This track was held as part of the Fifth International ICST Conference on Bio-Inspired Models of Network, Information, and Computing Systems (BIONETICS 2010), in Boston, MA, on December 1-3, 2010. The track consisted of seven peer-reviewed full papers on various topics relevant to adaptive networks. Dr. Thilo Gross (collaborator for this project) helped organizing this special track as a co-chair, and planned to give a keynote talk. Unfortunately his travel was canceled because of the inclement weather in Europe.

* STCAN 2011: Workshop on State-Topology Coevolution in Adaptive Networks. This workshop was held as part of the Eighth International Conference on Complex Systems (ICCS 2011), in Boston, MA, on June 27, 2011. The workshop hosted seven presentations selected based on abstract reviews. Compared to STCAN 2010, a broader range of application research areas was represented in this workshop, such as management and organizational sciences.

* STCAN 2013: Symposium on State-Topology Coevolution in Adaptive Networks. This symposium was held as a satellite symposium of the 2013 International School and Conference on Network Science (NetSci 2013), in Copenhagen, Denmark, on June 3, 2013. The event consisted of one keynote talk by Dr. Stefan Bornholdt and 12 contributed talks, which was a significant expansion from the past two STCAN meetings. Dr. Thilo Gross helped organizing this event as a co-chair. This symposium attracted a lot of audience, and the discussions were very active and productive. We believe this event contributed to the development of a research community on adaptive networks significantly.

* NetSci High 2011: International High School Student Poster Competition on Network Science. This new educational outreach program was developed in collaboration with the New York Hall of Science. Two poster sessions were organized: one in the 2011 International School and Conference on Network Science (NetSci 2011), on June 6-10, 2011, Budapest, Hungary, and the other in the Eighth International Conference on Complex Systems (ICCS 2011), Boston, MA, on June 26-July 1, 2011.

* NetSci High 2012: High School Student Research on Network Science. This was a continuation of the NetSci High poster competition organized in the previous year. It was again organized in collaboration with the New York Hall of Science (Dr. Stephen Uzzo and Ms. Catherine Cramer). In 2012, the program was run in the form of scholarships offered to participating high school student teams. Two student teams participated from the Binghamton area. Those teams were offered a scholarship to attend the NetSci 2012 conference in Evanston, IL, on June 18-22, 2012, and presented their posters. One of the students was also invited to give a short oral presentation at the NetSciEd symposium described below. This year, we also received a corporate donation to this program from BAE Systems.

* NetSciEd Satellite Symposium on Education @ NetSci2012: Infuse Network Science into K-12 and Undergraduate Education. This symposium was also organized and hosted in collaboration with the New York Hall of Science. Nine presentations were made by invited speakers who work on the intersection between network science and education. The PI also gave a presentation on his own experience supervising high school students' research projects on networks.

* Workshop on K-12 Science Education Outreach at Binghamton University. This workshop was organized in October 19, 2012, together with Dr. Zhongfei (Mark) Zhang in Computer Science. It aimed to bring all the parties involved in educational outreach activities at Binghamton University and local schools to discuss their approaches, exchange ideas, and brainstorm future developments as a community for engaging the school kids into scientific activities. More than two dozens of panelists participated and had very active and fruitful discussions about educational outreach.

* NetSci High 2013: High School Student Research on Network Science. Starting

this year, the NetSci High program became an NSF ITEST project "Network Science for the Next Generation", led by Boston University and the New York Hall of Science. The PI continued to participate in the ITEST project as a consultant. He also supervised one local student team from Vestal High School. They attended a NetSci High summer camp in 2012 and then presented their year-long research project at a NetSci High conference in the following summer. Their poster was also presented at the NetSci 2013 conference in Copenhagen, Denmark.

* NetSciEd2 Satellite Symposium on Network Science in Education @ NetSci2013. This symposium was also organized and hosted in collaboration with the New York Hall of Science. Eleven presentations were made by invited speakers who work on the intersection between network science and education. The PI was a co-organizer of this event.

Other: Academic meetings

Supporting Files

Filename	Description	Uploaded By	Uploaded On
attached-documents1.pdf	Published papers	Hiroki Sayama	09/29/2013
attached-documents2.pdf	Information about NetSci High	Hiroki Sayama	09/29/2013
attached-documents3.pdf	Information about NetSciEd symposia	Hiroki Sayama	09/29/2013
attached-documents4.pdf	Information about STCAN 2013, and others	Hiroki Sayama	09/29/2013

Participants

Research Experience for Undergraduates (REU) funding

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Benjamin James Bush	Graduate Student (research assistant)	9
Samuel Heiserman	Graduate Student (research assistant)	1
Chun Wong	Undergraduate Student	3
Hiroki Sayama	PD/PI	11
Jeffrey Schmidt	Graduate Student (research assistant)	11
Steven Krell	Undergraduate Student	2
Alex Hantman	Undergraduate Student	1
Jin Akaishi	Technical School Faculty	1

Genki Ichinose	Technical School Faculty	1

What other organizations have been involved as partners?

Name	Location
Boston University	Boston, MA
Chuo University	Tokyo, Japan
DRDC CORA	Ottawa, ON, Canada
Maine-Endwell High School	Endwell, NY
Max Planck Institute for the Physics of Complex Systems	Dresden, Germany
Memorial Sloan-Kettering Cancer Center	New York, NY
New York Hall of Science	Queens, NY
USMA West Point	West Point, NY
University of Bristol	Bristol, UK
University of Connecticut	Storrs, CT
Vestal High School	Vestal, NY

Have other collaborators or contacts been involved? N

Impacts

What is the impact on the development of the principal discipline(s) of the project?

This project has been producing a novel theoretical framework and a computational toolkit that is transforming the ways of studying the dynamics on and of complex networks and thereby achieve significant advances in the modeling and prediction of their temporal evolution.

What is the impact on other disciplines?

The outcomes of this project will be useful in many cutting-edge fields, including social network science, organizational research, network ecology and epidemiology, systems biology, bioinformatics, and many others. Areas of application include social network analysis, modeling and analysis of organizational behavior, and modeling and analysis of biological network formation. The developed framework will also serve as a generalized conceptual/mathematical 'language' for modeling, analyzing and discussing the dynamics of various complex systems, which will galvanize interdisciplinary discussion and collaboration across many different areas of applications. To facilitate cross-disciplinary discourses, international workshops/special sessions have been organized several times already.

What is the impact on the development of human resources?

Through collaboration with Dr. Thilo Gross at the University of Bristol (formerly at the Max Planck Institute for the

Physics of Complex Systems), the PI has acquired mathematical knowledge and skills for analytical study of adaptive network dynamics using moment closure techniques, as well as many creative ideas and insights into how one could effectively represent and analyze various dynamics of adaptive networks.

This project involves two graduate research assistants (Jeff Schmidt and Benjamin James Bush). Bush joined in Fall 2010 and has been working on the application of adaptive networks to social network modeling and analysis. He is from an underrepresented group (Hispanic). Schmidt joined in Spring 2011 and has been the main software developer of PyGNA, working on the implementation of the GNA framework in Python/NetworkX. Both students enrolled in the Ph.D. program in Systems Science at Binghamton University, and the PI supervises their work. Both students took a graduate course on computational modeling taught by the PI.

The two graduate students are receiving multidicsiplinary research training under financial support from this NSF award, including international collaboration with Dr. Thilo Gross at the University of Bristol, UK (formerly at the Max Planck Institute for the Physics of Complex Systems in Dresden, Germany) every summer. The PI and the graduate students (both in 2011 and 2012; only Schmidt in 2013) stayed in Dr. Gross's lab during the summers and had intensive discussions with him as well as his staff. The students' reflections on their learning through these international experiences are attached to this annual report. Schmidt also accompanied the PI in his visit to DRDC-CORA in Ottawa, Canada, in September 2011, and participated in the initial stage of the collaboration with DRDC-CORA.

Schmidt has obtained a Master's degree for his research on this project in Fall 2012. A conference paper based on his Master's thesis won the Best Studednt Paper award at the IEEE Symposium on Artificial Life in April 2013. In the meantime, Bush is expected to obtain a PhD for this research on this project by the end of 2013. Both students are currently working on journal articles that summarize their research outcomes.

In addition, the PI, Bush and Jin Akaishi (collaborator) participated in the supervision of local high school student teams during the Fall 2010/Spring 2011 semesters. They had weekly meetings with two student teams on a regular basis to discuss research progresses, tasks and directions. They all gained valuable educational experiences through these outreach activities. The PI continued supervising various high school student teams to date.

This project also involved several undergraduate assistants. Steven Krell (Bioengineering junior) was hired to assist the PI in organizing the STCAN 2011 workshop and the ICCS 2011 conference itself (for which the PI served as a Program Chair). While he did not conduct any research, Krell was able to attend the workshop/conference as a staff member and learned a lot about complex systems and network sciences. For research, Chun Wong (Bioengineering senior) was hired during Spring 2012 to help the PI develop the simulation software for the collaboration project with DRDC-CORA. He accompanied the PI and Schmidt in their visit to DRDC-CORA in Ottawa, Canada, in September 2011. Finally, Alex Hantman (Bioengineering junior) helped writing prototype codes for the collaboration project with Dr. Zhirong Bao during summer 2012.

What is the impact on physical resources that form infrastructure?

N/A

What is the impact on institutional resources that form infrastructure?

The new graduate course on complex adaptive networks produced in this project will serve as an educational resource for faculty and students at Binghamton University.

What is the impact on information resources that form infrastructure?

This project is producing PyGNA, a free software package of the GNA framework for modeling and analysis of complex adaptive networks, which will be a useful computational resource for broader research communities.

Moreover, the educational outreach program developed as part of this project, NetSci High, has come to be recognized very positively among the international network science community. It will serve as a continuing educational resource for those who want to initiate similar K-12 outreach programs that will bridge secondary education with cutting-edge scientific research labs.

What is the impact on technology transfer?

The software developed in this project is made publicly available from SourceForge.net. No technology transfer related action was taken yet.

What is the impact on society beyond science and technology?

The proposed GNA framework may help model and understand many real-world social/organizational/operational networks, which may help better inform policy makers and business practitioners. For example, we collaborated with DRDC CORA on GNA-based modeling of their operational networks. The outcome of this project may inform Canadian Defence authorities about what kind of organizational improvements will help make their SAR response joint systems more efficient. Similarly, our recent work on cultural integration after corporate merger may offer many valuable implications for how to make corporate M&A effective and successful.

Changes

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Jeff Schmidt, one of the two graduate research assistants involved in this project, was hired later in the second year because we could not hire a qualified student at first. This caused a small delay in the progress of the development of PyGNA. To continue hiring him for one additional year to complete the software development and evaluation, a no-cost extension request was submitted to, and approved by, NSF.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.