Next Generation Community Financial Cyberinfrastructure for Managing Systemic Risk

Report of a workshop, March 2013

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Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the University of Maryland, the University of Michigan, or any of the organizations affiliated with the workshop participants.

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> The financial and CS communities seek to bring about a new era of quantified external and internal oversight of financial activity, activity evolving under continuous competitive acceleration. We can only succeed if the foremost financial and computer science theorists and practitioners can meet, as we did here, to understand one another's frontier perspectives, problems, and vocabularies.
>
> – *Workshop participant Leonard Nakamura, Assistant Vice President, Federal Reserve Bank of Philadelphia*

EXECUTIVE SUMMARY

The Great Recession of 2008 and the continuing reverberations around debt and deficit in the Eurozone have highlighted significant limitations in monitoring and modeling national and global financial eco-system(s). In consequence, regulators are unable to forge knowledgeable and prudent policies, analysts are uncertain of the quality of their risk estimations, researchers are stymied in their ability to model markets and to predict behavior and outcomes, and firms may experience costly trading errors due to the use of sub-optimal risk management metrics.

The National Science Foundation and the Computing Community Consortium of the Computing Research Association co-sponsored a *Workshop on Next Generation Financial Cyberinfrastructure* on July 19-20, 2012. The goal of the workshop was to initiate a research discussion about the infrastructure challenges for effective financial information management. Over forty invited academic researchers, financial regulators, and industry practitioners participated in the event. The participants brought diverse perspectives and expertise in economics, computer science, finance, and information science, creating an intentionally interdisciplinary discussion.

President Obama signed the *Dodd-Frank Wall Street Reform and Consumer Protection Act* into law on July 21 2010. Among its many regulatory changes, the Dodd-Frank Act created an Office of Financial Research (OFR) with the mandate to establish a sound data management infrastructure for systemic-risk monitoring. The OFR should be a focal point for defining and implementing many of the responses to the challenges sketched above.

To provide the information required for systemic risk analysis, §154 of the Dodd-Frank Act mandates that the OFR will contain a Data Center (OFR/DC) to manage data for the new agency. Under the terms of the Act, the OFR/DC must:

- Publish financial instrument reference data,
- Publish legal entity reference data,

- Publish data reporting standards and formats, and
- Collect contractual positions and transactions data.

These requirements are specified in §154(b) of the Dodd-Frank Act itself. The Act further requires that the OFR/DC maintain data security and confidentiality.

In addition to the OFR/DC, the §154(c) of the Dodd-Frank Act also mandates that the new agency contain a Research and Analysis Center (OFR/RAC). The OFR/RAC must maintain computational and analytical resources to: measure and report on changes in systemic risk, conduct institutional stress tests, advise fellow regulatory agencies, investigate disruptions and failures, analyze proposed policies, and promote best practices in risk management.

In addition to the data resources mandated explicitly by the Dodd-Frank Act, the measurement and analysis performed by the OFR/RAC will require market prices and related data for the valuation of positions, development of models and scenarios, and the measurement of micro-prudential and macro-prudential exposures.

While there is considerable activity today in developing more sophisticated models of financial eco-systems and in developing more advanced regulatory tools, *all such work must be driven and informed by data*. Unfortunately, current financial cyberinfrastructure severely restrict the availability of data to market participants, regulators and researchers. These limitations commence with constraints on the data collection authority of regulators. They are exacerbated by the lack (or low acceptance) of ontologies and standards and protocols within the financial industry. Beyond these limitations is the inherent challenge of dealing with the complexity of financial information and meeting the diverse and sophisticated analyses required to model heterogeneous eco-systems.

Advanced computing technology can help to address many of these challenges and can be used to develop the next generation of community financial infrastructure. The workshop brought together a diverse community of academic researchers, regulators and practitioners. They articulated the range of multi-disciplinary research challenges and highlighted the urgent need for *community financial infrastructure*. An important challenge is the need to develop computational research frameworks, models and methods, in the spirit of past efforts to identify computational grand challenges in data intensive domains including the biomedical sciences, healthcare, climate change, etc. *The next generation of community financial cyberinfrastructure must provide a platform that can transform our current patchwork of approaches to monitoring and regulating systemic risk and must provide a unifying framework to identify computational grand challenges for improved financial monitoring and risk management.*

The result of the workshop was a recognition of the need for community financial cyberinfrastructure for monitoring and modeling financial eco-systems, based on the following:

- A blueprint for developing community infrastructure that builds synergy among multi-disciplinary needs and opportunities and academic disciplines.

- A detailed specification of the infrastructure including datasets, annotations, ontologies, tools, metrics, ground truth, benchmarks and use cases.
- A framework that can articulate each computational research challenge and link it to the community infrastructure resources and testbed(s) that is envisioned through this proposed effort.

The impact of the next generation of community financial cyberinfrastructure will be significant. Regulators will not be as blind-sided during future crises. There will be increasing synergy from applying computational technology, BIGDATA and Linked Data, and social media, to address difficult modeling and monitoring problems in financial eco-systems. This may result in improved tools for regulators, as well as fundamentally new designs of market mechanisms, recommendations, ratings, etc. On the educational frontier, the planned community financial cyberinfrastructure will nurture a new generation of multi-disciplinary scholars, at all levels, who will blend computational solutions with theories, models and methodologies from finance, economics, mathematics and statistics. An advisory committee of researchers from finance, economics and mathematics and representatives of the financial industry has been identified. The vision and implementation plan for community financial cyberinfrastructure will be developed by a steering committee of computational researchers and representatives from the software industry.

ORGANIZATION

Over forty invited academic researchers, financial regulators, and industry practitioners participated in the event. The participants brought diverse perspectives and expertise in economics, computer science, finance, and information science, creating an intentionally interdisciplinary discussion. A full list of the names and affiliations of the participants is available at the following site:
https://wiki.umiacs.umd.edu/clip/ngfci/index.php/Participants

There were several technology summaries from computer science researchers as well as interviews and panel discussions to highlight the challenges faced by finance researchers from academia and the government. The primary discussion of the workshop took place in several breakout groups. A detailed agenda for the workshop is available at the following site:
https://wiki.umiacs.umd.edu/clip/ngfci/index.php/Agenda

Organizers:

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INTRODUCTION

Recent events including the Great Recession of 2008 and the continuing debt and deficit challenges in the Eurozone have highlighted significant limitations in modeling national and global financial eco-system(s). This includes the lack of financial cyberinfrastructure to ingest and process numerous streams of financial transactions, as well as the accompanying data streams of economic activity, in real time. Also absent are open standards and shared semantics so that this data can be used to populate models of individual markets, financial networks and the interconnected eco-systems representing national or global financial systems. The limitations have been exhaustively described in [Cerutti et al 2012; Engle and Weidman 2010; IMF and FSB Report 2010]. There is an urgent need to develop computational research frameworks, models and methods, in the spirit of computational grand challenges in data intensive domains such as the biomedical sciences, healthcare, climate change, etc. The next generation of community financial cyberinfrastructure must provide a platform that can transform our current patchwork of approaches to monitoring and regulating systemic risk. The following *grand challenge* scenarios exemplify new tools and methods for regulators to deal with cataclysmic events:

- The ability to track financial products end-to-end along their supply chain. An extreme example is the mortgage supply chain, including sub-prime mortgage products, the asset backed securities into which individual mortgages were pooled, and finally the complex derivatives that were used to hedge bets against the securities. This lack of infrastructure continues to create problems in financial markets, the US housing market, and the courts, as state attorneys general struggle with robo-signed documents and improper and potentially illegal foreclosures.
- The ability to produce a "heat map" of our financial system transactions and accompanying economic activities, very much like a global weather map, so that one can identify financial weather patterns, pinpoint areas of high activity or vulnerabilities based on topology, warfare, political uncertainty, etc.
- Models of the global financial marketplaces and their interconnections, or the multi-party network of legal entities (financial institutions) that participate in complex financial contracts, as well as the network of relationships among them. Such models will provide the capability to run large-scale simulations to understand how these systems will perform under stress. We note that federal regulators in 2008 had to make expensive and drastic policy decisions about bailouts and stimulus spending, without real-time access to such models or simulation results.
- A significant amount of human activity is captured in new media – social media and social networks, as well as in traditional media – newswire, large document collections, etc. These resources can be a proxy for financial markets and can capture many aspects of human behavior including sentiment, persuasion, etc. Such knowledge can be extracted and mined to create more sophisticated models of financial markets. We note that there have been many recent successes in combining human language technologies, machine learning and data/text mining, e.g., in computational social dynamics or socio-computing in the humanities and the social sciences.

1. Community Description and the Need for Infrastructure

The workshop brought together a diverse community of academic researchers, regulators and practitioners, from the following disciplines:

- Computer science and information science (data management and data mining; visual analytics; information retrieval; human language technologies; machine learning; knowledge representation and reasoning; semantic Web; BIGDATA).
- Finance (financial informatics, risk management, and financial engineering) and financial accounting.
- Mathematics, economics and operations research related to financial information modeling.

The consensus of the community was that there was a *significant deficit* in computational and mathematical modeling and reasoning, as well as a dearth of best practices for standards and ontologies, data sharing protocols, quality metrics, etc. Hence, all interested actors have been unable to ingest market information in a timely manner, and to determine what information might be missing. Broader impacts of the planned community financial cyberinfrastructure include the following:

- The academic community will have access to community resources required to examine and analyze actual market operations and behavior.
- Regulators, analysts, and the financial press will reach a better understanding of capital market operations to forge knowledgeable and prudent financial policy.
- Business analysts will have increased confidence in their internal risk and accounting numbers.

Further, there will be increasing synergy from applying computational technology, BIGDATA and Linked Data, and social networks and social media, to address difficult modeling and monitoring problems in financial eco-systems. This may result in improved tools for regulators to monitor financial systems as well as fundamentally new designs of market mechanisms, new ways to reach consumers, new ways to exploit the wisdom of the crowds to review and rate financial products, to make recommendations, etc.

The financial industry has historically been a leader in utilizing and driving advances in computational methods, and it is one of the largest consumers and producers of BIGDATA. Nevertheless, the industry does not have a history of making appropriate datasets available as community infrastructure for research. A key reason is that information asymmetry is a prime advantage in a financial trade. The *data quality gap in finance* is an evolutionary outcome of years of mergers and internal realignments, exacerbated by business silos and inflexible IT architectures. Difficulties in unraveling and reconnecting systems, processes, and organizations – while maintaining continuity of business – have made the problem intractable. Instead, data are typically managed on an ad-hoc, manual and reactive basis. Workflow is ill defined, and data reside in unconnected databases and spreadsheets with multiple formats and inconsistent definitions. Integration remains point-to-point and occurs tactically in response to emergencies. Many firms still lack an executive owner of data content and have no governance structure to address organizational alignment or battles over priorities. The last decade has seen the emergence of a patchwork of standards and protocols such as SWIFT (bank-to-bank message transfer) and FIX (Financial Information eXchange is a messaging standard for the real-time electronic exchange of securities transactions). These have been developed as standalone protocols for specific purposes and lack a shared semantics, e.g., a shared controlled vocabulary or ontology.

The Office of Financial Research (OFR) has a mandate under the Dodd-Frank Act of 2010 to collect all required data inputs for managing systemic risk. However, requirements to ensure the privacy and confidentiality of fully identified data, and the need to provide a continuous audit of secure access to the data, behind a firewall, naturally lead to constraints that limit the ability of the OFR to make the acquired data widely available to the public. In some cases, the OFR may even be unable to share data collected through its authority even though portions of such data may already be made available to the public through some other possibly unauthorized channel. *The community infrastructure development activities envisioned in this proposal are therefore a valuable complement to the data collection authority and activities of the OFR.* Further, a potential outcome of developing community infrastructure may be improved methods for data de-identification and protocols to allow for greater data sharing by the OFR in the future.

2. Vision and Architecture for Community Infrastructure

We focus on the challenge of managing systemic risk in this CRI-CI-P (planning) document. The vision for exploiting BIGDATA, e.g., real time streams of all financial transactions, other signals of economic activity, social networks and social media data streams, Linked Data, etc. will be explored more fully in developing the implementation plan of the full CRI-CI proposal.

Financial data for systemic risk management can be classified as follows:

- Financial instrument reference data: Information on the legal and contractual structure of financial instruments such as prospectuses or master agreements, including data about the issuing legal entity and its adjustments based on corporate actions.
- Legal entity reference data: Identifying and descriptive information such as legal names and charter types, for financial entities that participate in financial transactions, or that are otherwise referenced in financial instruments.
- Positions and transactions data: Terms and conditions for new contracts (transactions) and the accumulated financial exposure on an entity's books (positions).
- Prices and related data: Transaction prices and data used in the valuation of positions, development of models and scenarios, and the measurement of micro-prudential and macro-prudential exposures.

The vision for developing community financial cyberinfrastructure will explore multiple approaches to accommodate a diversity of requirements. One approach is to start with a *seed collection* of highly curated data objects, and to exploit public or private collections, utilizing text extraction and human language technologies, to enhance and enrich the seed dataset. A vastly different approach would apply *scalable methods* from network analysis, machine learning, information retrieval, semantic Web, Linked Data, etc., to create large interlinked and annotated collections, with varying levels of completeness and quality. There is also a significant need to apply *knowledge representation and reasoning* methods to financial contracts so yet another approach will rely on combining methods for machine readable contracts, formal logics and reasoning, etc. We briefly comment on the datasets, tools, ontologies, metrics, metadata, user cases and a variety of artifacts that comprise community financial cyberinfrastructure. Details of some exemplars are provided in a later section.

DATASETS

- Ground truth datasets a la the TDT4 that has been used for topic detection human evaluation [TDT2004]. These datasets will be used to specific metrics, determine performance baselines, etc.
- Starter or seed datasets that have been manually curated and enriched, e.g., MIDAS collection from IBM [Hernandez et al 2012] or the Hoberg SEC collection [Ball et al 2012]; details will be provided in a later section.
- Large representative collections, e.g., for sampling, de-identification, etc. There are multiple portals that can provide such collections, e.g., the SEC/EDGAR portal.

TOOLS/ONTOLOGIES/METRICS/METADATA

- The Financial Industry Business Ontology (FIBO) includes a semantic model of concepts, their relationships and abstractions, as well as an operational ontology that targets pragmatic operational implementations. For example, using a semantic reasoner, representations in W3C RDF OWL and the FIBO, one can implement an end-to-end application to extract data from a spreadsheet and to classify undifferentiated financial swaps into their real asset classes.
- Karsha: The Smith School of Business and the Lanka Software Foundation have incubated the Karsha FOSS project to develop a recommendation tool and document search engine with respect to the Financial Industry Business Ontology (FIBO) [Karsha DASS]; details will be provided in a later section.
- Metadata, namespaces and RDF schemas, quality metrics, etc. will be developed in cooperation with/in alignment with the recommendations of the Financial Stability Oversight Council (FSOC) Standing Committee on Data.

USE CASES / SIMULATION SCENARIOS / CICI and LEI/ TESTBEDS/OTHER ARTIFACTS

- The proposed Legal Entity (LEI) Identifier and its precursor the CFTC Interim Compliant Identifier (CICI) comprise an important first step in providing a standard to uniquely identify each participant and to (partially) capture relationships among participants. The CICI has been structured to satisfy ISO 17442. The 20 digit LEI code, is expected to be identical to that of the CICI for those firms, which received a CICI identifier [ISO 17442 LEI].
- Workflows around the reporting of financial trades are not well documented. They are designed with a focus on an after-the-crisis mindset. The 2008 crisis highlighted the urgency for more proactive approaches to monitoring and modeling financial eco-systems. The use case scenarios from the 2010 Workshop Report [Flood et al 2010] will be developed as a resource to identify data quality metrics and data gaps and to measure the benefit of the reported data.
- The planned infrastructure will include a variety of tools and testbeds. An exemplar agent-based simulation testbed for automated trading [Wah et al 2012] is discussed in a later section.

BEYOND SYSTEMIC RISK

The 2008 financial crisis increased the focus on systemic risk. At the same time, there is a vast eco-system of financial markets and regulatory agencies and SIFIs (systemically important financial institutions) that interacts with the consumer and businesses. Our vision of shared infrastructure will embrace some of these eco-systems.

- GSE: Privately held corporations with public purposes created by the U.S. Congress to reduce the cost of capital for certain borrowing sectors of the economy. Examples of GSEs include the Federal Home Loan Bank, Federal Home Loan Mortgage Corporation (Freddie Mac), Federal Farm Credit Bank and the Resolution Funding Corporation.
- CFPB (Consumer Financial Protection Bureau); students loans; credit card debt; housing loans; "Know Before You Owe" campaign. The CFPB was also set up by the Dodd-Frank Act of 2010, and has taken a lead in using social media to educate the public on mortgage products, credit card debt, student loans, etc.

ACCESS AND DISSEMINATION

There are several examples of community infrastructure, portals, model organism databases, etc., that have been sponsored by the NSF and the NIH. Exemplars include the UCI Machine Learning Repository [Frank and Asuncion] and WormBase [Harris et al 2010]. We will follow best practices from both the computer science and bioinformatics communities to identify a plan for access and dissemination, and data management best practices and protocols. Every effort will be made to use open standards and protocols and to make all resources available to the public.

3. Steering Committee and Advisory Committee

ADVISORY COMMITTEE

- Lewis Alexander, Chief U.S. Economist, Nomura. Formerly Counselor to the Secretary of the Treasury.
- Richard Anderson, Economist, Federal Reserve Bank of St. Louis.
- Mike Atkin, CEO, Enterprise Data Management Council.
- Andrei Kirilenko, Professor of the Practice of Finance at the Sloan School of Management, Massachusetts Institute of Technology. Formerly Chief Economist, CFTC.
- John Bottega, Chief Data Officer, Bank of America.
- Michael Bennett, Head of Semantic Technologies, Enterprise Data Management Council.
- Albert "Pete" Kyle, Charles E. Smith Professor of Finance at the Smith School of Business, University of Maryland.
- Joe Langsam, former Managing Director, Morgan Stanley.
- Andrew Lo, Charles E. and Susan T. Harris Professor at the Sloan School of Management, Massachusetts Institute of Technology.
- David Newman, Vice President for Enterprise Architecture, Wells Fargo.
- Chester Spatt, Pamela R. and Kenneth B. Dunn Professor at the Tepper School of Business, Carnegie Mellon University.

- Nancy Wallace, Lislie and Roslyn Payne Professor at the Haas School of Business, University of California, Berkeley.

STEERING COMMITTEE

Elisa Bertino	Purdue University	Data management; cybersecurity.
Andrea Cali	University College of London	KR; formal reasoning.
Michael Franklin	University of California Berkeley	BIGDATA; data management.
Juliana Freire	NYU	Data management; provenance.
Johannes Gehrke	Cornell	Data management.
Lise Getoor	University of Maryland	Machine learning.
Georg Gottlob	Oxford University	KR; formal reasoning.
Gerard Hoberg	University of Maryland	Finance
Eduardo Hovy	CMU	Human language technologies
Vagelis Hristidis	University of California Riverside	Data management; social media.
H.V. Jagadish	University of Michigan	BIGDATA; data management.
Brad Malin	Vanderbilt University	Bioinformatics; privacy.
Philip Resnik	University of Maryland	Human language technologies.
Ben Shneiderman	University of Maryland	Visual analytics.
Michael Wellman	University of Michigan	AI; agent based modeling.

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