An invitation for Collaboration on
Normalized Systems
University of Antwerp – CTU Prague

Over the last 3 years, collaboration has been established between the University of Antwerp and the Czech Technical University (CTU) in Prague in the field of Normalized Systems. The collaboration currently consists of education, research and hands-on tool development.

This document describes a number of master thesis topics that we propose in the context of this collaboration for CTU students in the academic year 2017-2018.

Introducing Normalized Systems

In the digital transformation our society is currently experiencing, every aspect of society and economics is pervaded by ICT systems. Developments such as IoT, machine learning, blockchain, business intelligence and others, are spearheading efforts to develop massive amounts of software systems. At the same time, unprecedented demand for change is developing. Governments, companies and other organizations are emphasizing the need to innovate, to be trendsetters and leaders in their markets, or at least to follow and react to the developments in their environment.

The combination of both developments, i.e. the increasing size, complexity and omnipresence of software systems with the need for unprecedented change, poses daunting challenges. It is well-known in industry that software systems at the moment are typically very expensive to develop and maintain. Notwithstanding the enormous progress in research and practice in software development over the last 50 years, their ability to change or evolve is limited, even at the current rates of change. Indications include high maintenance budgets, the inability to find sufficient workforce and the need to outsource, ICT projects that are over time and over budget, and many others. This is related to the fact that ICT development at this point in time remains a largely manual, heuristic (experience-based), framework- and technology-specific, and error-prone process, which is far less industrialized than other engineering domains.

Research on Normalized Systems Theory was initiated in 2006 at the University of Antwerp by Prof. Dr. Herwig Mannaert and Prof. Dr. Jan Verelst. Its goal was to study whether the evolvability of large, mission-critical software systems can dramatically be improved, for example by an order-of-magnitude. This ambitious goal was pursued by using well-known and proven concepts from other scientific areas, such as stability from systems theory and entropy from thermodynamics, which have already led to similar productivity gains in the past, by industrializing production of artefacts in their respective domains.

Since 2006, a solid theoretical foundation for Normalized Systems in the domain of software architectures for information systems has been developed and published in 2 books, 5 PhD’s and 50+ scientific articles. Development of Normalized Systems Theory went hand-in-hand with industrial practice: over 40 NS Applications have been developed and are currently in production in a wide variety of contexts: from small-scale to large-scale systems, from government to companies, from administrative information systems to industrial systems in trending markets such as solar panel (PV)-monitoring. Some are brand new, others have been in production and have evolved, for up to 8 years.
The way of building NS Applications in practice is heavily dependent on an industrialized software factory, featuring code generators and other tools (called NS Expanders and the NS Prime Radiant) uniquely complying with the stringent requirements of NS Theory, as well as on an evolution/maintenance-process of continually regenerating or rejuvenating landscapes of NS Applications over time.

While using several ideas and frameworks from mainstream software development, such as microservices, continuous integration, aspect-oriented programming, agile development and others, both the tools and especially the underlying theoretical foundation make the development of NS Applications fundamentally different: NS Theory influences heavily all aspects of the standardized, industrialized, and repeatable process of software development and evolution.

Some quotes published in our second book illustrate the innovative and fundamental nature of NS:

“Based on solid physical and informational theoretical concepts, NST provides the basic “eigenvectors” that span the software space, equivalent to the atoms of which all matter is made of, or the 4 nucleobases (C,G,A,T) of which DNA’s nucleotides are composed.”

Prof. Dr. José Tribolet, Full Professor of Information Systems, Computer Science and Engineering Department, University of Lisbon

“The application of NST to the design of evolvable software systems is definitely the most exciting contribution I have seen in the software industry for quite some time.”

Prof. Dr. Jorge Sanz, Chief Innovation Officer Retail Banking - IBM Research, Director of Business Analytics Center, National University of Singapore

Ba/Master/PhD thesis: Research collaboration

Based on the current theoretical foundations and industrial applications that have already been realized, addressing a new and ambitious set of research topics now becomes realistic, challenging the state-of-the-art in several domains related to software engineering and modularity, and providing the combination of theory with application in real-world systems and organizations.

Several research domains/topics are available for collaboration in the context of a Ba/Ma/Phd thesis:

- Visualization

By developing NS Theory and tools and developing 40+ applications that are currently in production, a large-scale Java codebase (order of magnitude of several millions of LoC) now exists with unique modular characteristics (as they are based on the stringent requirements of NS Theory). The NS Prime Radiant offers a uniquely powerful view on the modular structure of this codebase, even though this view is currently non-graphical.

We believe that new and advanced (possibly 3D-) visualization techniques can be developed to show the unique and advanced modular characteristics of NS Applications. Visualizing individual applications and landscapes of applications becomes highly useful, for example, for inspecting the status of an NS Application, certain quality characteristics or other. This research aims at developing both theoretical foundations and practical implementations of advanced (possibly 3D-) visualization techniques of key aspects that determine the evolvability of modular structures. The results can be tested on real-world software systems.
- Reuse and Evolvability in Conceptual modeling

NS Theory has implications in several ways for conceptual modeling: first, the NS Prime Radiant and NS Expanders provide a very powerful implementation platform for conceptual modeling languages. Second, applying NS Theory to conceptual modeling suggests that unprecedented levels of evolvability in models can be reached by making them highly modular and fine-grained. The latter has implications both for the constructs of conceptual modeling languages and their use in the development of conceptual models of individual applications or, on the other hand, reusable reference or domain models. The combination of evolvable conceptual models with a powerful implementation platform opens up an unique development environment for large, mission-critical systems of the future.

- NS software quality inspection and refactoring

The software architecture of an NS Application consists of a so-called skeleton, to which customizations (or craftings) are added. These are plug-in, add-on software modules amounting up to less than 5% of the code of a finished, production-ready NS Application. Nonetheless, in a landscape of NS Applications, hundreds or even thousands of these customizations or craftings could exist. This research is aimed at developing theoretical foundations and practical tools for inspecting the quality of the customizations. Examples could include the automated detection of reuse possibilities based on detection of similar patterns in the codebase, automated refactorings and/or others.

- Extraction of business rules from existing/legacy systems

Many of the requirements for new applications are currently embedded in existing systems, perhaps even legacy. The first part of this research aims at developing theoretical foundations as well as tools for extracting or re-engineering requirements from existing systems, with a particular focus on extracting business rules. The second part of this research focuses on investigating the concept of modularity of business rules, based on NS Theory, including the transformation of traditional to modular business rules.

- Business Intelligence: introducing modularity based on NS Theory

NS Theory focuses on evolvability in modular structures, which are omnipresent in many domains in ICT, including (transactional) information systems. The movement towards Business Intelligence has added massive data marts to the information systems in the IT landscape of many organizations, making data available for mining and other applications. This research focuses on how concepts from modularity and NS can be applied in the context of Business Intelligence, in order to make these massive systems more evolvable. This topic currently seems under-explored, even though it is clear that evolvability issues can occur both in the ETL-stage and during mining. This research has the potential to open up new research directions in Business Intelligence, and to create a common theoretical foundation between Business Intelligence and information systems, with new possibilities for their integration and evolution.

- NS Documents

NS Theory has recently also been applied to modular structures in domains outside ICT. One example is the study of modular documents. For most organizations, managing versions and variations of documents is difficult and expensive, even with recent document management technology. Even electronic documents, i.e. websites, pdf’s etc., prove to be a highly rigid and expensive source of modular structures. NS Theory has been applied to study how next-generation
documents can be built, enabling the power of modularity by building prototypes of code generators for documents, eliminating combinatorial effects, and generating hundreds or thousands of versions and variations of (electronic) documents automatically. This research focuses on both theoretical foundations of evolvable documents, combining both existing technologies in document management with NS Theory, and the development of (prototypes of) code generators for documents. Real-life applications of modular documents are available both at CTU and in Antwerp.

- Blockchain

Blockchain proposes a new way to deal with transaction processing based on massive and highly automated transaction handling between large amounts of heterogeneous stakeholders. However, building such systems at industrial strength implies building systems of unprecedented scale and complexity, while addressing concerns such as integration, security, and above all evolvability, i.e. the ability to evolve in what will certainly be a fast-changing business environment.

This research topic focuses on investigating of role of evolvability in Blockchain, both at the technical level and the functional level (for example, smart contracts). Besides defining the required evolvability, the applicability of Normalized Systems Theory (NST) to provide this evolvability can be researched at both levels. The goal of this research aims at enhancing Blockchain with aspects from NS, as a first step towards a new, mission-critical Blockchain technology, having proven evolvability as a unique characteristic.