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Graph Databases for Systems Engineering Applications

A Proposal for the Research or Creative Experience for Undergraduates (RCEU) Program Summer 2018

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Project Summary: Remarkable advances in sensing, computing, communications, and material technologies within the last twenty years have enabled new functionality and levels of performance of modern engineering systems. These changes are shaping all aspects of human life from housing (smart buildings and houses), to driving (intelligent/autonomous vehicles), through manufacturing goods (smart factories) and services (internet of things). Engineering systems are increasingly automated, distributed, interconnected and autonomous making their successful design and operation a complex endeavor. High profile failures such as the Denver Airport baggage handling system and the Concorde airplane crash illustrate the challenges ahead. Model based systems engineering (MBSE) has emerged as a valuable approach to manage complexity in system design. However, traditional MBSE approaches are ill-equipped to tackle enduring problems along the system life cycle. Those challenges include, capturing and keeping track of frequent changes in requirements, integrating data and models of various types, uncovering emergent behaviors and modeling, visualizing and simulating multi-layered and complex dynamic interactions. The overall goal of this research project is to identify and investigate avenues for graph databases and related emerging technologies to help address above-mentioned issues.

Unlike relational databases, the underlying data model of graph databases put relationships and nodes on equal footing. This enables efficient, persistent storage, processing, and querying of not just nodes but also connections between them in constant-time. Integrating graph databases with semantic web and machine learning techniques have been proven effective in areas like medicine (e.g., finding new treatment uses for drugs that are already on the market) or networking (e.g., predict information system incidents). These capabilities and others make graph database and technologies of great interest for MBSE applications. For instance, nodes in the graph can be used to represent system components at various levels of abstraction while relationships are used to establish semantic context for entities and the system as whole. Through careful modeling and systematic integration, connected property graph have the potential to provide a powerful, unified representation and repository of the system that can be queried against system requirements, integrated with higher (or same) levels system models.

Through this project, the student will gain hands-on experience in systems engineering, software programming and development. He/she will get the opportunity to learn about conceptual system modeling, graph databases and technologies. In turn, his/her work will facilitate future research in MBSE of complex systems.

Student duties

The student selected for this project will be responsible of the following:

1. **Literature review:** The student will gather state-of-the-art related research, studies and

- tools (open source and off-the-shelf) relevant to graph technologies and their application to system modeling and design. A brief report on the state-of-art, challenges and opportunities will be written and submitted by the student.
2. ***Evaluate graph database/technology environment***: The student will be responsible for downloading, configuring and evaluating the capabilities of a selected graph technology tool chosen to support the investigation. This task involves organizing and testing example codes and applications.
 3. ***Modeling***: The student will create, evaluate and analyze increasingly complex graph models of systems. The models will be used to test above research ideas and see how well they help address identified MBSE challenges. Standalone and integrated (across tool) models will be developed and lessons learned from the effort will be documented. The default system of application is an unmanned aerial system (UAS). However, Dr Petnga is open to consider other engineering systems proposed by the student.
 4. ***Project plan***: the student will develop and submit a plan of work with reviews and milestones. The plan baseline will be used to evaluate his/her progress and performance.
 5. ***Manuscript Preparation***: Dr. Petnga encourages all undergraduate student researchers to write up their results in the form of a manuscript for publication. The RCEU participant will prepare the manuscript(s), which may include data from other sources.

Faculty Supervision and Mentoring

The prospective RCEU student will receive close mentoring from Dr. Petnga during the project. The student will report to Dr. Petnga on a weekly basis (minimum) and is encouraged to seek his advice whenever a problem is encountered. The performance of the student will be evaluated based on his working progress as well as the quality of the work.

Student Qualifications

There are no systems engineering coursework or academic standing prerequisites. However, senior level standing in the college of engineering or computer science is needed. This project does involve writing programs for graph-based modeling. Thus, understanding of databases would be beneficial and knowledge of Java and Eclipse IDE will come in handy. A good working ethic and a high motivation toward research are also expected from the qualified candidate. Candidates interested in pursuing graduate studies in Systems engineering are particularly encouraged to apply.