Project: Online documentation for FDS

Advisor: McDermott, Randall

Division: Fire Research Division

Begin the process of developing online documentation for the NIST Fire Dynamics Simulator (FDS). All documents are currently posted in PDF format. But most modern software packages have online documentation generated by something similar to Sphinx. This and alternatives will be explored. In particular, the ability to transfer LaTeX math documentation will be evaluated.

Project: Digital Twin Development for a Robot Arm

Advisor: Shao, Guodong

Division: Systems Integration Division

A laboratory scale robot workcell for digital twin research is being established. Among other equipment, the workcell comprises two UR5e robots. A digital twin will be developed for the robot arms using data collected using the MTConnect standard. The digital twin will help monitor, analyze, and optimize the manufacturing process and also help test methods and tools that support robot workcell automation. The SURF student will work with the NIST researchers to analyze the collected data, build and validate a digital twin, and integrate the digital twin with other systems.

Project: Hierarchical Data Structure Development to Support Digital Thread and Digital Twin Applications

Advisor: Shao, Guodong

Division: Systems Integration Division

Digital twins can digitally represent a physical manufacturing element, e.g., a part. However, to represent a part being manufactured, data from multiple stages of the Product Lifecycle may be needed. In each of these stages, specific data standards and formats may be used. It is challenging to relate the different information to a part. A digital thread could help link all the data to support the digital twin development. Currently, there is no framework or structure can easily and efficiently support the store, representation, and exchange such data. In this summer, the SURF student will work with the NIST researchers on novel data storage solutions, such as Hierarchical Data Format (HDF5), to represent product lifecycle data, which will leverage digital twin applications in manufacturing; perform research on existing work in digital thread and digital twin; and develop use case of the selected structure to represent data from product lifecycle stages; and demonstrate digital twin applications using the data structure.

Project: Study of Degradation Mechanism and Failure Mode of Polymeric Components used in Photovoltaics

Advisor: Gu, Xiaohong

Division: Materials Structural Systems Division

Understanding the degradation modes of polymeric components used in solar cells during services is critical to the development and assurance of photovoltaic technology. In this study, the degradation of polymeric backsheets aged in the accelerated laboratory conditions and in the fielded modules under different climates will be analyzed using spectroscopic and mechanical techniques such as attenuated total reflection Fourier-transform infrared spectroscopy (ATR-FTIR) and tensile tester. The mechanisms of chemical and mechanical degradation will be studied. The results will be used to understand the root causes of the backsheet failure and provide scientific basis for material selection and product development.

Project: Analyzing and Applying Data from Irradiance Database for Indoor Energy Harvesting

Advisor: Shore, Andrew

Division: Building Energy and Environment Division

Internet-of-Things devices are becoming increasingly more used in the home. Harvesting the available ambient indoor light energy using Photovoltaic (PV) mini-modules can help reduce electrical needs and power these devices. To better assess the year-round feasibility of this energy harvesting approach, the PV Characterization Lab is measuring the spectrum and intensity of the available light at three different locations in the Net-zero Energy Residential Test Facility (NZERTF). The student intern will help analyze this data to determine seasonal effects and the typical available spectra and intensities at each location. The student will have a further opportunity to synthesize and test a model spectrum on various PV mini-modules in our indoor light test setup to study effectiveness and ability to power a wireless device for a duration of time.

Project: Measurements of Thermal Properties of Organic Phase Change Materials Modified by Thermally Conductive Fillers

Advisor: Kim, Jae Hyun

Division: Building Energy and Environment Division

Phase Change Materials (PCMs) are used as latent heat storage sources of thermal energy through a phase change. For PCMs, magnitudes of latent heat of fusion and thermal conductivity are important governing factors for storing and releasing of thermal energy efficiently. This project will investigate thermal properties of a selected organic PCM with different ratios of fillers. Changes in the thermal behaviors and thermal conductivities of the modified PCM will be characterized. The experimental results will help us understand the relationship between heat storage behaviors and thermal conductivities of the modified composite organic PCMs.

Project: Study of Pyrrhotite Reactions in Concrete

Advisor: Watson, Stephanie

Division: Materials Structural Systems Division

Damage to concrete structures in building construction in Connecticut was attributed to iron sulfide mineral pyrrhotite and results in decomposition and structure cracking. Some states passed building codes to prevent this issue, but there are no standardized methods or concentration limits to assess pyrrhotite abundance. NIST developed reference standards (RM) to provide an accurate, consistent pyrrhotite analysis in concrete. This project focuses on optimizing an x-ray fluorescence method to quantify sulfide and sulfate species in RMs compared to foundation specimens. An experimental design to create a model aggregate to better understand pyrrhotite reaction mechanisms and rates will also be investigated.

Project: 3D Additive Manufacturing of Cement Based Materials

Advisor: Martys, Nicos

Division: Materials Structural Systems Division

3D printing of concrete is a relatively new approach to the placement of concrete and other cement based materials. This project will evaluate the stability of different printed structures given the viscoselastic properties of the printing fluid, whose properties may change with time. Such information may help provide guidelines for the suitability of certain structures for 3D printing as well as the printing process.

Project: Understanding Time-dependent Behavior of Alternative Cementitious Mixtures for Additive Manufacturing

Advisor: Cook, Rachel

Division: Materials Structural Systems Division

Concrete, a ceramic composite, is the most-utilized man-made material worldwide. With cement production responsible for 9%-to-10% of global anthropogenic CO2 emissions, research focused on improving the sustainability and resiliency of U.S. infrastructure is imperative. In this project, a student will have the opportunity to study the effect of recycled plastic materials on the time-dependent behavior of sustainable cement blends for the purpose of additive manufacturing (AM). Experimental work will include isothermal calorimetry and small amplitude oscillatory shear (SAOS) measurements. The results of this work will help to improve understanding of sustainable mixtures generally and for the purposes of AM.

Project: Study of Fire-Affected Concrete

Advisor: Strack, Cody

Division: Materials Structural Systems Division

Climate change is increasing the frequency of fire-related events triggering more instances of concrete exposed to conditions that can reduce its expected service life. Many studies use furnaces and other artificial means to study fire-affected concrete, whereas actual fire events can lead to irregular distribution of heat compounded by the inherent heterogeneity of concrete. This study will utilize NIST's National Fire Research Laboratory to simulate real fire conditions within concrete mixes of various compositions. Samples will be analyzed via microscopy, image analysis, and mechanical tests to evaluate extent of damage and link fire conditions to expected structural performance.

Project: Technical Language Processing for Improved Document Annotation and Community Resilience

Advisor: Fung, Juan

Division: Materials Structural Systems Division

Vast amounts of technical data exist in published documents, including those used to conduct community resilience and climate adaptation planning. Current process of reading and summarizing such documents by hand requires expert judgment and is incredibly time-consuming, which limits our ability to create large-scale datasets. The goal of this project is to harness text mining and natural language processing techniques to create a semi-automated human-in-the-loop tool to assist domain experts with annotating technical documents. This groundbreaking tool will be used to summarize current climate adaptation and community resilience approaches nationwide and assist other researchers with similar data challenges.

Project: Estimating the Coarse Aggregate Sieve Distribution in Concrete from Observations Made on a Cut Surface.

Advisor: Snyder, Kenneth

Division: Materials Structural Systems Division

Forensic situations can arise whereby a researcher would like to determine the ASTM C 33 sieve distribution that was used for a particular concrete mixture. Alternatively, one might want to know whether two difference concrete mixtures were made using the same coarse aggregate sieve distribution. For this project, the plane cut surfaces of hardened concrete will be studied to characterize the coarse aggregate size distribution for comparison to other distributions. The student will perform statistical tests to determine the sample size required to distinguish two similar distributions, and will study the qualitative "distance" two distributions need to be before they can be distinguished.

Project: Generating Weathered Microplastic Particles Using the NIST SPHERE

Advisor: Sung, Li Piin

Division: Materials Structural Systems Division

This project will focus on generating weathered plastic particles with the NIST SPHERE, where macro-samples or films of plastics are UV-weathered while immersed in water (or simulated ocean water) or under high humidity, dry conditions. ATR-FTIR and laser scanning confocal microscopy will be used to characterize chemical properties of UV-degraded surface and morphology (the size and distribution) of nano-/micro- plastics particles as a function of UV exposure time. The outcome of this project would provide spectral database (FTIR) of weathered plastics, particles sizes of the microparticles at various temp and generation of more relevant, weathered microplastic particles.

Project: Using Resonant Frequency Testing Methods to Characterize the Extent of Damage in Concrete Cores Taken From an Existing Building.

Advisor: Snyder, Kenneth

Division: Materials Structural Systems Division

A forensic study of an in-service concrete structure typically involves collecting concrete cores for mechanical testing (e.g., compressive strength). Although the values are used to characterize the concrete properties, there can arise situations where the observed properties are much lower than expected. There can be a number of reasons for this to occur: 1) the concrete has an inherently lower strength due to actions/steps taken during construction; 2) the concrete has been damaged due to chemical attack (e.g., corrosion, sulfate attack) or due to unanticipated loads (e.g., earthquakes, hurricanes). How to incorporate the measured value into the overall distribution of measurements requires knowing which category the sample is in.

ASTM C 215 resonant testing of cores can be used to estimate the Young's and shear moduli of a sample. This project will extent this test by determining whether the nature of the resonance is correlated to damage withing the core. Specifically, the nature of the isolation of the resonant frequency, with respect to other frequencies present.

Project: The Effect of Wavelength and Intensity in the UV Region on Polymer Degradation.

Advisor: Jacobs, Deborah

Division: Materials Structural Systems Division

The new 0.5-m NIST SPHERE is now operational. The new device must be tested thoroughly before the technology can be transferred to industry. Here, the effect of lower UV wavelengths on the degradation pathway and their impact on the reciprocity law will be investigated. The student will run experiments on a polymer under different exposure conditions by varying filters to determine if the same degradation mechanism is followed independent of which filter is used. Analysis methods will include Fourier Transform infrared (FTIR) and dynamic mechanical analysis (DMA) to monitor the changes in chemical and mechanical properties.

Project: Fire Modeling Software Verification and Validation

Advisor: McGrattan, Kevin

Division: Fire Research Division

NIST develops and maintains two computer fire models. One, the Fire Dynamics Simulator (FDS), is a computational fluid dynamics model. Its documentation includes separate verification and validation manuals that describe the results of hundreds of calculations and comparisons to experimental test data or analytical solutions. This database of V&V cases is expanding, and there is a need to incorporate new data and new cases into the repository. The project shall involve working with experimental fire test data, running numerical simulations, and comparing the results of both. A particular emphasis is on quantifying the uncertainty of the model.

Project: Additive Manufacturing Part Inspection Data Registration Software Development

Advisor: Feng, Shaw

Division: Systems Integration Division

The number and types of sensors used for in-process monitoring laser-powder bed fusion processes for metal Additive Manufacturing (AM) are increasing. Each sensor is independent of others. The datasets from different sensors have different reference frames for reporting the collected data. Furthermore, post-process inspection data adds another layer of complexity that needs to be addressed. AM data registration is needed to help resolve the issue of monitoring the powder fusion processes and predicting the material properties in the part. This summer research work involves developing fundamental algorithms and a software tool for processing and registering data, using available X-ray Computed Tomography data as an example. Functions of the tool include image segmentation, feature extraction, and defect identification. Some programming and image processing skills are required, for example, Python, C++, Java Script, ImageJ, or Matlab. The applicant must be interested in additive manufacturing or 3D printing.

Project: Performance of Schools, Shelters, and Hospitals in Hurricane Maria

Advisor: Young, Camila

Division: Materials Structural Systems Division

In February 2018, the NIST Director established a National Construction Safety Team (NCST) to conduct a technical investigation of the effects of Hurricane Maria on Puerto Rico. The goal of this summer research project is to support the NCST investigation by collecting and analyzing information on the performance of critical buildings in Hurricane Maria, to evaluate the adequacy of existing design standards and codes for these facilities. The SURF student will work with the NIST mentor to mine school, shelter, and hospital information from various data sources (e.g., satellite and aerial imagery, NOAA datasets, damage reports, news media reports etc.) and contribute to a geodatabase. This damage data will then be analyzed, along with information on the wind hazard, to explore how the hazard levels encountered at the facility site impacted damage and loss of function of the facility.

Project: Assessment of Polymer Composite Degradation During Long-term Use in Outdoor Infrastructure Applications

Advisor: Goodwin, David

Division: Materials Structural Systems Division

Data and test methods are currently lacking to assess the health and performance of polymer composite materials used as retrofits and protective coatings on buildings and infrastructure in outdoor environments. Accelerated laboratory tests and outdoor exposure of polymer composites help to assess timelines for loss of functionality during service life and inform replacement schedules. Measurement methods, including chemical and microscopic methods, will be used to track degradation in both accelerated laboratory tests and outdoor tests. Fiber-reinforced polymer (FRP) composite samples weathered outdoors as well as FRP and polymer nanocomposites degraded under accelerated ultraviolet exposure and freeze/thaw cycling will be assessed.

Project: Understanding Strength Development in 3D Printed Cementitious Materials

Advisor: Newman, Aron

Division: Materials Structural Systems Division

Interest in replacing the conventional form work and concrete placement with 3D printing of cementitious materials has increased in the last several years. The stability of these structures needs to be better understood, particularly at early age where there is a risk of creep that can compromise structural integrity. This research project will measure the frequency response of hardened cement pastes through dynamic mechanical analysis. The measured storage modulus and creep from this method will be compared to the indentation response using a microhardness tester that records a load – displacement curve to evaluate for modulus and creep. Measurement values from these two methods can potentially provide guidance on optimizing cement mix designs for building robust 3D printed structures.

Project: Laser Powder bed Fusion Additive Manufacturing Data Analysis

Advisor: Lu, Yan

Division: Systems Integration Division

This project will investigate the correlation between in-process monitoring data and ex-situ measurements for laser powder bed fusion (PBF) additive manufacturing (AM). The results will enable the fusion of multiple-modality in-situ data for part quality prediction. The student will analyze several data sets published by NIST, including high-speed melt pool images and high-resolution layerwise images from the “Overhang Part X4” build using the NIST Additive Manufacturing Metrology Testbed, as well the X-Ray CT data of the as-built parts. Both classic machine learning and deep learning methods should be investigated to establish the relationship between in-process measurements and XCT data.

Project: Semantic Models for Embeded Intelligence of Building operation

Advisor: Delgoshaei, Parastoo

Division: Building Energy and Environment Division

Semantic Web technologies promise new opportunities for the efficient management of information and knowledge in the built environment. Semantic models of buildings lower the cost of analytics and enhance intelligent control across buildings. This project aims to use a set of software tools for creating RDF models of Building Automation Systems (BASs) for Heating Ventilation and Air Conditioning, Lighting, and shading devices according to the evolving ASHRAE 223 Semantic Data Model for analytics and automation applications in buildings.

Project: Development of Non-Destructive Polymer Degradation Measurements in Photovoltaic Modules

Advisor: Aiello, Ashlee R.

Division: Materials Structural Systems Division

Prevention and understanding of early failure mechanisms in photovoltaic modules is needed to economize solar energy. The polymeric components in photovoltaic modules degrade during outdoor exposure, which can result in multiple failure mechanisms including cracking, delamination, and discoloration. While many characterization methods are well suited for polymer degradation studies, they require disassembly of the module and are limited to post-mortem analysis. This project will focus on the development of new non-destructive measurements to study polymer degradation in either fully assembled modules or under in-situ conditions (e.g. during exposure to temperature, humidity, or mechanical strain).

Project: Real-time pose Measurement to Support Robot Inspection

Advisor: Qiao, Helen

Division: Intelligent Systems Division

The use of robots in high-precision applications has been increasing, for example, robot real-time inspection. The capture, analysis, and real-time feedback of inspection results in users making the best decision on time. For robot inspection, the robot is performed as a carrier of the inspection sensor. The robot's accuracy needs to be assessed and the dynamic motions need to be measured to satisfy the requirement of registering inspection data. The robot arm's position and orientation information are used to register the sensor data for full 3-D analysis. The National Institute of Standards and Technology (NIST) has developed a novel smart target (patent) to support the precise measurement of a robot's position and orientation. The smart target is mounted on the object (e.g., end effector or tool of a robot arm) whose accuracy is to be ensured in order to measure and track the object's six-dimensional (6-D) position and orientation. The smart target consists of fixed-wavelength light pipes and two high-precision rotary gimbals. The light pipe structure defines a coordinate frame that contains 6-D information. One measurement of the smart target can output the pose of the object (6-D measurement – x, y, and z position, roll, pitch, and yaw orientation).

Project: Risk and Uncertainty in Community Resilience Planning

Advisor: Gore, Christina

Division: Applied Economics Office

A flexible methodology to value the socioeconomic impacts, avoided costs, and expected benefits is needed to evaluate the return-on-investment of community resource allocation decisions to reduce future economic damages from disasters, while accounting for uncertainty and behavioral influences on decision-making, such as risk profiles and learning. To develop this framework, first a complete documentation of uncertainty and risk tolerance needs to be completed. This documentation is likely to include heuristics and other behavioral ways that individuals and communities make decisions, especially about community resilience in the built and natural environments when faced with a diverse set of resource allocation alternatives.

Project: Joint Cognitive Work to Formulate Business Transactions

Advisor: Denno, Peter

Division: Systems Integration Division

We are interested in enabling non-programmers at small manufacturers to formulate for themselves the information technology needed to transact with their large corporate customers. The general idea is to do this task as joint (human/AI) cognitive work (JCW). We developed a "mapping language," RADmapper, that facilitates JCW by analyzing samples expressed in its own abstract syntax trees. We seek someone with strong math or CS skills to use RADmapper to generate and characterize language samples. Example characterization might include identifying paths from target data back to source data, or mathematical structures such as natural transformations.