

**NATIONAL SCIENCE FOUNDATION (NSF)  
RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU) SITE:**

**EXERCISE - Explore Emerging Computing in Science and Engineering**

**Salisbury University**

**Application and Information Packet**

**Program Dates: May 26 - August 4, 2020 (tentatively)**

**Application Deadline: March 10, 2020**

This packet contains:

1. NSF REU – EXERCISE project description
2. Student participant benefits
3. Student participant eligibility
4. Application information and process
5. Sample summer research projects
6. A three-page application form with five parts
7. Two recommendation forms

**Send Applications and Direct Inquiries to:**

Dr. Enyue (Annie) Lu

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<http://faculty.salisbury.edu/~ealu/REU/REU.html>



## 1. Project Description

**EXERCISE** (**Ex**plore **Em**erging **Co**mputing **i**n **Sc**ience and **En**gineering) is an interdisciplinary project that explores emerging paradigms in parallel computing with data and compute intensive applications in science and engineering.

In the current fast-paced global world with advances of new technologies, information and data are growing exponentially. It is becoming increasingly difficult to process information and data by a single processor computer. Emerging paradigms in parallel computing provide new approaches to solving problems with large data sets and high computational complexity. A *parallel computing system* is a set of processing units, either locally located or distributed across network, that can process information and data in parallel, thus can solve problems of a larger size and get them done faster. In the *EXERCISE* project, students will apply emerging parallel computing models including GPU computing with NVIDIA CUDA (a local parallel processing system) and MapReduce computing on Amazon EC2 (a distributed parallel processing system) to tackle data and compute intensive problems in computer networks, image and signal processing, and geographic information system.

The goal of the *EXERCISE* project is to offer student participants from primarily undergraduate institutions (PUIs) a valuable research experience in the emerging parallel computing field. Salisbury University will be the host institution with substantial collaborations with the University of Maryland Eastern Shore, the University of Maryland College Park, and the University of Maryland Baltimore County, and the Johns Hopkins University. The project consists of two components: a spring online workshop and a ten-week summer research camp. The spring workshop is to prepare students with background knowledge in parallel computing and to help them develop interests in one of the research projects to be offered by a group of experienced faculty mentors in summer. The summer research program will allow students to carry out featuring projects via a comprehensive approach that combines theory, algorithms, implementation, analysis, simulations, and experiments.

## 2. Benefits

- \$600 allowance will be provided for traveling to REU site: Salisbury University (SU).
- \$5,000 stipends for full-time participation in the entire ten-week summer program.
- Housing and meals provided during ten-week summer program at SU
- Field trips and social activities
- Research opportunities in emerging computing with applications in science and engineering

## 3. Eligibility

- United States citizens or permanent residents
- A STEM (Science, Technology, Engineering, and Mathematics) major
- Completing at least sophomore year of study
- GPA 3.0 or above
- Programming knowledge in either of C, C++, Java, or MATLAB
- Willing to participate in the four-week spring pre-program online workshop
- Must be committed to participating in the summer program for the full ten-week period

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#### 4. Application

**All the application materials must be received by the deadline: March 10, 2020** (Late applications will be considered if we have space remaining in the program). Underrepresented students (women, minorities, students with disabilities) and students from primarily undergraduate institutions (PUIs) are particularly encouraged to apply.

A completed application includes:

- A three-page SU REU application form, which can be downloaded online: <http://faculty.salisbury.edu/~ealu/REU/ApplicationForm.docx>;
- An [online CISE REU Common Application form](#);
- A transcript from your current institution. While an official transcript is preferred, an unofficial one is acceptable. An official transcript is required when you are selected as the REU participant finalist;
- Letters of recommendation from two faculty who have worked with the applicant. Two copies of recommendation letter forms are included in this packet and can be also downloaded online: <http://faculty.salisbury.edu/~ealu/REU/RecommendationForm.docx>. The recommendation letters should be sent by the faculty directly to us in either of email, mail or fax.
- A proof of U.S. citizenship (passport, birth certificate, or similar) or permanent residency ("green card") is required when you are selected as the REU participant finalist. Please understand that U.S. citizenship/permanent residency is a requirement for the NSF REU funding and we cannot change or waive it.

#### 5. Sample Research Projects

The research project background materials and problem sets will be posted in the spring pre-program online workshop. The research projects will be finalized in the first week of the summer REU program. The research projects will be designed to allow undergraduate student participants to be at the forefront of new innovations, yet work within an environment that is manageable for their level of expertise. Some sample research projects are listed as follows.

##### 5.1 Graph mining for large-scale networks using MapReduce

**Faculty Mentor: Dr. Enyue (Annie) Lu**

Analyzing patterns in large-scale graphs, such as social and cyber networks (e.g. Facebook, LinkedIn, Twitter), with millions, even billions of edges has many important applications such as community detection, blog analysis, intrusion and spamming detections, and many more. Currently, it is impossible to process information in real-world large-scale networks with millions even billions of objects with a single processor. To overcome single processor limitations, a cluster of computers with multiple processing elements operated in parallel connected by a distributed network are used to solve large-size problems and reduce processing time.

In this project, students will try to enumerate and identify important graph patterns. The network is modeled as a graph. Each person is represented as a vertex and a mutual friendship between people is represented as an edge in the graph. Finding a pattern in a real-

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world network is equivalent to finding a subgraph in a large-scale graph. We will map graph decomposing operations into a series of MapReduce processes. The proposed MapReduce algorithms will be implemented in Amazon Elastic MapReduce. We will also do performance comparison and analysis for the proposed MapReduce algorithms and simulation results.

## 5.2 Implementation of parallel iterative improvement stable matching algorithms

**Faculty Mentor: Dr. Enyue (Annie) Lu**

In a graph, a set of independent edges (no two edges in the set are adjacent) is called matching. Matching algorithms are widely used in many applications including database search, image processing, pattern analysis, and scheduling. The stable matching problem was first introduced by Gale and Shapley in 1962. Given  $n$  men,  $n$  women, and  $2n$  ranking lists in which each person ranks all members of the opposite sex in the order of preference, a stable matching is a set of  $n$  pairs of man and woman with each man and woman in exactly one pair, where there is no pair who are not matched who both prefer the other to their current partner. Gale and Shapley showed that every instance of the stable matching problem admits at least one stable matching, which can be computed in  $O(n^2)$  iterations. For real-time applications such as switch scheduling, the algorithm proposed by Gale and Shapley is not fast enough.

To date, the most well-known parallel algorithms for the stable matching problem are all run on theoretical parallel computing models such as CRCW PRAM. In this project, students will implement a parallel iterative improvement (PII) stable matching algorithm with linear time average performance. For real-time applications with a hard time-constraint, the PII algorithm can terminate at any time during its execution, and the matching with the minimum number of unstable matching pairs can be used as an approximation to a stable matching. The PII algorithm will be implemented using MPICH2 from Argonne National Lab, NVIDIA CUDA-enabled GPUs, and MapReduce computing on Amazon EC2. The goal of the project is to examine the parallelism of the stable matching by using the practical PII algorithm. We will implement the PII algorithm on the software level, measure its speedup against the sequential approaches, find out its efficiency and applicability, and investigate the parallelism limits of the stable matching algorithms.

## 5.3 Anomaly Detection for Network Data Using MapReduce

**Faculty Mentor: Dr. Enyue (Annie) Lu**

As the volume of collected data grows at an unprecedented rate with the recent technology advances, information retrievals on very large data sets have becoming a beneficial and challenging task. Anomaly detection, which is used to identify abnormal events or patterns that do not conform to expected events or patterns, has been a very useful methodology to perform predictive modeling checking of available data and become increasingly complex to detect intrusion through network records due to large volumes of network traffic data.

In this project, we will develop a new framework that combines graph modeling with MapReduce computing techniques to tackle anomaly detection on network record data at extreme scales. Graph is an expressive data structure and has been widely used to model

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complex data in many applications. By graph modeling, data will be represented as vertices and the relationship (e.g., similarity in spatial, temporal, or semantic attributes) within data are represented as edges in a graph. We will detect the anomalies by analyzing the graph generated by the network data. We plan to tackle the problem in the following three research steps. In the first step, we analyze the characteristics of the data and develop an effective graph model for the data. In the second step, we will develop efficient MapReduce graph-based anomaly detection algorithms and analyze their performance. In the last step, we will test the proposed algorithms and verify their performance using real-world network data.

#### 5.4 GPU accelerated medical image reconstruction and processing

**Faculty Mentors: Dr. Yuanwei Jin**

Image reconstruction and processing is a rapidly developing field based both on engineering, mathematics, and computer science. Algebraic Reconstruction Technique (ART) is a well known reconstruction method for computed tomography (CT) scanners. Although the ART method has many advantages over the popular filtered back-projection approaches, due to its high complexity, it is rarely applied in most of today's medical CT systems. The typical medical environment requires fast reconstructions in order to save valuable time. Industrial solutions address the performance challenge using dedicated special-purpose reconstruction platforms with digital signal processors (DSPs) and field programmable gate arrays (FPGAs). The most apparent downside of such solutions is the loss of flexibility and their time-consuming implementation, which can lead to long innovation cycles. In contrast, research has already shown that current GPUs offer massively parallel processing capability that can handle the computational complexity of two-dimensional or three-dimensional cone beam reconstruction.

In this project, students will accelerate a new iterative image reconstruction algorithm called "propagation and backpropagation (PBP)" image reconstruction method using Matlab computing with NVIDIA CUDA-enabled GPUs. Through the project, students will learn the basics of Matlab parallel computing for medical imaging with GPU support and gain understanding of the benefits of parallel processing for large scientific computing tasks based on a real-world medical imaging problem. Furthermore, students will be able to verify their algorithms using experimentally collected data through data measurement systems funded by a Department of Defense award and an NSF Major Research Instrumentation award.

#### 5.5 Deep Learning and Data Analytics for Remote Sensing Applications

**Faculty Mentors: Dr. Yuanwei Jin**

With massive amounts of computational power, machines can now recognize objects and translate speech in real time. Research in this area attempts to make better representations and create models to learn these representations from large-scale unlabeled data. Deep learning is part of a broader family of machine learning methods based on learning representations of data. Deep learning algorithms attempt to learn multi-level representations of data, embodying a hierarchy of factors that may explain them. Various deep learning architectures such as deep neural networks, convolutional deep neural networks, and deep belief networks have been applied to fields like computer vision, automatic speech recognition, and natural language processing where they have been demonstrated to be

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effective at uncovering underlying structure in data and producing state-of-the-art results on various tasks.

In this project, we will focus on remote sensing applications such as radar target recognition and feature extraction of acoustic dispersion characteristics. For example, automatic target recognition based upon a sequence of synthetic aperture radar (SAR) images is an important task for both military and civilian applications. By employing emerging deep learning method applicable to SAR images and implementing the algorithms on commercial off-the-shelf graphics processing units (GPUs), significant improvement in recognition performance is expected.

## **5.6 Exploring the Design of Optical Interconnected Multicore Computer Architectures**

**Faculty Mentor: Lei Zhang**

In pursuing more powerful computing capability, multiple and even many computing cores are integrated into a chip. As a result the bottleneck of computing is shifted from the how fast a core can compute to how fast cores can transfer data to each other. By replacing the traditional electrical wire to optical waveguide, in the Optical Network-on-Chip (ONoC), computing cores are integrated to one chip by which they can communicate via lights. In addition, the ONoC offers better energy conservation because of the higher power efficiency in optical transmission. These outstanding properties enable the ONoC to be the most promising candidates in constructing the next generation super computers.

In this project, we will explore the ONoC system design and development process. Students will be exposed to the advanced computer architecture concepts, optical computing theories, optoelectronics fundamentals, photonic VLSI design basics, and dynamically reconfigurable ONoC architectures. Through the project, participants will study the methodology of computing system architecture design, explore network topologies, play with mathematical tools, and develop software for simulation.

## **5.7 Personality-Augmented Intelligent Agents and Their Behaviors in HPC**

**Faculty Mentor: Dr. Randall Cone**

Visual representation and analysis of textual works have often aided human learning and understanding. In the Digital Age this is particularly true, given the advent of natural language processing, the wholesale availability of general programming languages, and the maturation of digital visualization. In our research, we eschew disciplinary boundaries to view and analyze classic literary and other textual works in unconventional ways. We study these texts with a sequence of progressively sophisticated content analysis and feature extraction software packages, many of which renders a useful artistic visual representation of a given text. To examine the entire corpus of an author's (or group of authors') works, appealing to the power of HPC is a natural choice.

We have recently begun to take the above mentioned content analysis and feature extraction research into the realm of Artificial Intelligence (AI). Using a bootstrap of cognitive and emotional reaction vectors, we endow artificially intelligent agents with personalities, then observe their reactions to sets of textual information. This work currently incorporates the

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following technologies: WordNet, Word2Vec, neural networks, and a novel AI framework written in the Python programming language. Our future plans are to extend this work into distributed computing environments and HPC (via mpi4py), strongly coupling it with a study wherein we establish groups of personality-endowed AI to study a population of such intelligences and their behavior.

## **5.8 Massively Parallel Machine Learning**

### **Faculty Mentor: Joseph Anderson**

Many modern computing challenges rely on massive amounts of data gathered -- from the user, the environment, a network, or other sources. The difficulty of processing this data has swiftly outpaced even industrial-grade computing hardware. Instead of trying to simply apply standard algorithms and approaches on a larger scale, the goal of this project is to explore which computational techniques can be adapted or re-formulated specifically for high-performance computing environments. Applications include medical imaging data, signal processing and recovery, compressed sensing, and neural networks.

## **5.9 High-Dimensional Convex Geometry and Optimization**

### **Faculty Mentor: Joseph Anderson**

Every person, as well as machine, constantly makes choices. The classical way to approach making choices is to consider balancing the cost of the choice versus the benefit of the choice; this is often referred to as optimization. In many modern machine learning applications (autonomous robots, self-driving cars, signal processing, medical imaging), these choices become more complicated and also more consequential. Convex geometry is a field of mathematics that offers powerful analytical tools for scientists to not only develop efficient computational techniques for such decisions, but offer rigorous theoretical guarantees about their performance.

This project will consider several important open problems from convex geometry, which have important relationships to machine learning and data analysis. Students will balance rigorous theory with experimental study, using software to approach currently open questions in convex geometry and optimization theory.

## **5.10 Parallel Processing for AI Opponents in Games**

### **Faculty Mentor: Joseph Anderson**

Computer games often rely on the implementation of “smart” adversaries to engage their players in challenging, yet rewarding, game content. However, as games become more sophisticated and allow the player more and more freedom of interaction with the world, the problem of simulating a formidable opponent -- one who is unpredictable, skilled, yet believable -- becomes computationally challenging. Traditional techniques for Artificial Intelligence break down quickly when there are too few constraints on the opponents’ behavior.

This project will focus on developing algorithms for AI behavior which take advantage of high-performance computing environments, with a focus on parallel computing and large-scale simulation.

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## NSF REU EXERCISE 2020 --- Application Form

**Application Deadline: March 10, 2020**

Please type or print legibly. Complete all the fields. If needed, you can attach supplemental documents or extend any of the table cells.

**Print Name** \_\_\_\_\_ **Home School** \_\_\_\_\_

### Part I. Personal Information

Fill in an online CISE REU Common Application form available at  
<http://faculty.salisbury.edu/~ealu/REU/REUCommonApplication.html>

### Part II. Academic Information

Please list all the computer science, mathematics, engineering, and any other courses that you have taken (along with grade received) that might be beneficial with this REU project:

List the courses you are taking in the Spring 2020 that are **not** listed on your transcript, using both course number and title:

Please identify any prior experience you have that will assist you with this project:

Rate your programming language proficiency and parallel computing skill levels from 5 (highest) to 1 (lowest), or 0 (no knowledge):

Java ( ) ; Python ( ) ; C++ ( ) ; C ( ) ; MATLAB ( )

Hadoop MapReduce ( ) ; CUDA GPU ( ) ; MPI ( )

Others (List below):

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**Part III. Project Preference**

Your preference for one project or another does not play any role in the selection process. Please select two that interest you the most. Write the project title here:

- 1.
- 2.

Or describe any other projects you would like to do:

**Part IV: Reference Information**

List two faculty members who will be submitting letters of recommendation for your application. We will not contact the letter writers and you must ask them to send their letters directly to us.

**Reference 1:**

|              |                |
|--------------|----------------|
| Faculty Name | Title          |
| Department   | Institution    |
| Office Phone | E-mail Address |

**Reference 2:**

|              |                |
|--------------|----------------|
| Faculty Name | Title          |
| Department   | Institution    |
| Office Phone | E-mail Address |

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**Part V: One Page Statement of Research Interest and Career Goals.**

**This statement should describe:**

- Your interest in participating in this NSF REU – EXERCISE site at SU
- Your general career goals
- Your professional accomplishment and other research or industrial project experience if there is any
- Your strength and weakness

**Signature** \_\_\_\_\_ **Date** \_\_\_\_\_

I HEREBY CERTIFY THAT THE INFORMATION I HAVE PROVIDED ON THIS APPLICATION IS ACCURATE TO THE BEST OF MY KNOWLEDGE. I UNDERSTAND THAT PROVIDING FALSE INFORMATION COULD DISQUALIFY ME FROM PARTICIPATION IN THIS PROGRAM.

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## NSF REU EXERCISE 2020 --- Recommendation Form

**Application Deadline: March 10, 2020**

***To be completed by the Applicant***

Applicant's Name: \_\_\_\_\_  
Last First M.I.

College or University: \_\_\_\_\_

***To be completed by the Recommender***

Name and Position/Title: \_\_\_\_\_

Organization: \_\_\_\_\_ Department: \_\_\_\_\_

Telephone: \_\_\_\_\_ E-mail: \_\_\_\_\_

How long have you known the applicant and in what capacity?  
 \_\_\_\_\_

Using "X" in the boxes below, please rate the applicant in the following areas:

| Area                           | Excellent | Very Good | Average | Below Average | No knowledge |
|--------------------------------|-----------|-----------|---------|---------------|--------------|
| Academic Achievement           |           |           |         |               |              |
| Research Ability and Potential |           |           |         |               |              |
| Intelligence, Quick Learning   |           |           |         |               |              |
| Hardworking, Independency      |           |           |         |               |              |
| Responsibility, Maturity       |           |           |         |               |              |
| Ability to Work in a Team      |           |           |         |               |              |

On a separate sheet, please tell us in narrative form why you endorse this student for the REU-EXERCISE Summer research Program. Be sure to address what you know about the student's academic achievement and professional experience; participation in extra-curricular activities; and work in and out of class. Please address what you think is important to know about this student, including more details on the ratings provided above. We are particularly interested in the candidate's motivation, hardworking, intelligence, and research potential. We welcome any information that will help us to gauge this student's potential to benefit from the REU summer research program at Salisbury University. The recommendation letters can be sent to us directly in email, mail or fax:

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Telephone: \_\_\_\_\_ E-mail: \_\_\_\_\_

How long have you known the applicant and in what capacity?  
 \_\_\_\_\_

Using "X" in the boxes below, please rate the applicant in the following areas:

| Area                           | Excellent | Very Good | Average | Below Average | No knowledge |
|--------------------------------|-----------|-----------|---------|---------------|--------------|
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| Responsibility, Maturity       |           |           |         |               |              |
| Ability to Work in a Team      |           |           |         |               |              |

On a separate sheet, please tell us in narrative form why you endorse this student for the REU-EXERCISE Summer research Program. Be sure to address what you know about the student's academic achievement and professional experience; participation in extra-curricular activities; and work in and out of class. Please address what you think is important to know about this student, including more details on the ratings provided above. We are particularly interested in the candidate's motivation, hardworking, intelligence, and research potential. We welcome any information that will help us to gauge this student's potential to benefit from the REU summer research program at Salisbury University. The recommendation letters can be sent to us directly in email, mail or fax:

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