

# Chapel

Proposal - Google Summer of Code 2021

## Project Proposal

### **Project Title**

Matrix Exponentials.

### **Introduction**

#### **1) Background and Current Studies**

I'm pursuing Master's in Computer Science at Northeastern University, Boston. I have previously worked in an e-commerce team at Oracle Pvt Ltd, India as a Software Developer Engineer for 2.5 years. I had an undergraduate degree in Computer Science from Birla Institute of Technology and Science, Pilani (BITS Pilani).

#### **2) Relevant work**

I have been first acquainted with Matrix exponentials in my undergraduate as part of the Linear Algebra. Linear Algebra course has fascinated me owing to the techniques the subject suggests to manipulate the objects such as lines and planes in the vector space in linear and rotational aspects. Solving matrices for solutions using Factorization methods like SVD, LU, PCA has its application in innumerable fields like Image processing, Machine learning, Decision systems. One important concept in Linear algebra is the ability to take the exponential of a matrix. Matrix exponentials are used in solving systems of linear differential equations. The theoretical implications of the matrix exponentials have interested me right from my undergraduate. Also, owing to my exposure to Operating systems coursework in my undergraduate years, I developed an interest in multi-threaded applications, specifically, to handle the intricacies involved in parallelizing the operations and resolving dependencies. I believe I can make use of the concepts from Linear Algebra, Operating Systems, and Algorithms to make a finer product. I also believe that I can use these skills to further improve the POC that I have developed for the Matrix exponentials.

### **3) Why GSoC?**

Since the time I have started doing my Masters, I have been missing the Developer aspect of my life which I enjoyed for the last 3 years. I see GSoC as a wonderful opportunity to fill this void. Time and again, I always find few aspects within me that I can improve as a developer and I believe GSoC helps me accelerate this self-improvement process. Most importantly, I have never been part of an open-source community before and I always wish myself to be seen as part of a bigger community doing a greater good (there is so little that you can achieve independently) and I see GSoC as a genesis to the vision I carry.

### **4) Why Chapel?**

I was first introduced to chapel by one of Brad's presentations. I was enlightened by the fact that one of the efficient ways to deal with the growing need for data-intensive tasks (like training Neural Networks) is to achieve parallelization. I see Chapel as a meticulous blend of a language that is as near as possible to python and yet offers data parallelization. When I started developing for Chapel, I discovered the features like distributed arrays (dmapped) which offered unique ways to achieve parallelization, and I (being in academia) felt that academia has been heard. Apart from this, I have always wanted to be part of developing a programming language from scratch. Also, I believe there is a lot of scope for development for chapel (Arkouda for instance: to make it as desirable as numpy; the need for native implementations for many algorithms). Thus, I wanted to be part of this craft.

### **5) Expectation**

With this opportunity, I wish to bond well with the community, establish connections and be a team player and work together for the betterment of the community. I wish to use the fullest capabilities of Chapel language to offer the best product the community desires. I also wish to discover the idiosyncrasies of the language and wish to be part of developing them.

### **6) Availability**

English has been my first language since my childhood and I'm well versed with both my spoken and my written English. I have secured distinction in all my English language exams I have written so far. I do not have any other commitments this summer and I plan to dedicate my time to develop with Chapel.

I do not plan to go on a vacation this summer owing to the pandemic scenario in the United States.

## Contact

- Name : Sai Prasanth Duvvuri
- Email: prashanthduvvuri@gmail.com
- GitHub/gitter nick : prashanth018
- Telephone : +1 617 712 9334
- Country of Residence : United States
- Timezone : EDT
- Typical Working Hours : 11:30-13:30, 15:00-19:00, 22:00-05:00 (EDT)  
15:30-17:30, 19:30-23:30, 03:00-10:00 (UTC)  
(If needed, I can start my day earlier or stretch my work hours.)
- Language : English

## Coding Experience

### 1) Experience with Programming Languages

During my undergraduate years, I mostly used C, C++ during my first 2 years and python for the next 2 years for course projects. During my first internship at UnitedHealth Group, I had an opportunity to work on Object-relational Mapping in C#. During my 6 months tenure at VMware and 2.5 year tenure at Oracle, I had worked on Java where I worked on multiple features as a Software Developer. I have been developing for Chapel since the start of this year, which is January 2021. I would rate myself as an expert in C, C++, Python, Java; intermediate in C#, Chapel.

### 2) Experience with Compiler Development

As part of a project in my undergraduate years, I have built a compiler for a subset of Context Free Grammar of Ada programming language. [This](#) refers to the project where I have built the lexer for the chosen CFG and then implemented an LR Parser in C++. I also had exposure to the working of file systems in a Virtual and Distributed environment during my time at VMware.

### 3) Are you familiar with git, make, gdb, gcc?

I'm familiar with gcc, make as part of the assignments and coursework in my undergraduate years. My time in the industry has helped me get well versed with git, crucible, swagger, and wiki documentation.

#### **4) Experience being part of Team Development**

Firstly, Team development has always helped me achieve things in a faster and polished way rather than being an Individual Contributor. During my tenure at Oracle, I had an inherent predilection to make connections in the team and across because of which I was able to have a quicker overview of the product and also helped me understand different perspectives of it. I was able to work on tougher and not so straight forward issues through the interaction and rapport I had with the teams. A Team environment sets the expectations facilitating a smoother workflow and helped me abide by the coding standards, conserve the code quality and preserve the modularity. A Team environment's expectation of accurate business communication helped me develop the ability to articulate clear and concise messages. It also helped me develop credibility by providing accurate information while displaying a strong commitment to deadlines by planning well ahead and passing relevant information or blockers on time.

#### **5) What is the biggest project you have worked on as a software developer? Your role and takeaways?**

I would grade my contribution to the native Machine Learning toolkit at Oracle as my biggest project spanning 1 year during which I learned immense things. I developed a Voice-based search system to aid visually disabled users and a native Sentiment Analysis tool to personalize the user catalog according to his/her product feedback and a Product return predictive model to assess the likelihood of a product return in real-time while customers put together their shopping basket. I joined the team as a fresher and over time I have transitioned into a key member and been handed time-bound customer-specific issues requiring me to provide quick and infallible fixes. Daily scrums, feature assignments, and hard deadlines taught me discipline. I learned to conceptualize all the scenarios before implementation aiding me to write clean code. Letting me develop as an independent thinker, the corporate world has taught me that changes are inevitable and uncontrollable making me realize that the only thing I can control is the way I address it.

#### **6) What have you already contributed to the Chapel project?**

Below are a few of the contributions I made to the Chapel community.

- [#17058](#) (merged): (Chpldoc not properly generated for few use cases).

- [#17523](#) (open): Matrix exponentiation using Scaling and Squaring Algorithm.
- [#17380](#) (open): Adding Checksumming to Mason.
- [#17168](#) (open): Changes to choice method of Random module to support sampling on N-Dimensions.

## Survey

### 1) Had you heard of Chapel before the summer of code? If so, where?

I heard about the Chapel in one of the educational videos on youtube. It was a video by Brad in which he has outlined the uses of Chapel, walked through the code and specifics of the language. I have realized the potential good that this language could do to the graduate community and hence started contributing.

### 2) What was the first question about Chapel that I could not find an answer to quickly?

Initially, when I took up chpldoc issue, I was not sure about the execution flow. I wanted to debug through the flow (specifically AstToText.cpp) to understand the issue. I did not have experience with gcc debugger. During this phase, I had a difficult time figuring out a solution. I eventually guessed the flow and validated the guesses with print statements.

### 3) What will keep you actively engaged with the Chapel community after the summer?

One way I can stay connected with the Chapel community is by using the language in my daily life. A stronger commitment of the Chapel community would make Chapel as desirable as possible and in turn, keeps the contributors (me) actively engaged even after the GSoC. Apart from this, an encouraging peer would also help me be engaged with the Chapel community going forward.

### 4) Are you applying to any other organizations for this year's GSoC?

No, Chapel is the only organization I intend to apply to in this year's GSoC.

## Prerequisites

### 1) What operating systems do you work with?

I work with Linux, Ubuntu 20.04 flavor.

**2) Are you able to install software on the computer you are planning to use?**

Yes, I'm able to install software on my computer.

**3) Will you have access to a computer with an Internet connection for your development?**

Yes, I will be well connected throughout the summer. In case of unavoidable disconnections (if any), I would ensure to communicate it with the co-developers and authority.

## **Self Assessment**

**1) What does useful criticism look like from your point of view?**

I see constructive criticism as a necessary evil and it (if handled constructively) always brings the best out of an individual. In such an event, I often take my time to evaluate the feedback and enumerate the given suggestions. Personally, my end goal is to never receive the same feedback twice. If I do then I re-evaluate my evaluation process and try to do my best. I also recognize the time and energy invested by the reviewer giving me the feedback and do my best to take the feedback seriously. I do my best to not take the personal experiences (with the reviewer) into account and try to comprehend the feedback in the words of a well-wisher.

**2) What techniques do you use to give constructive advice? How do you like to receive constructive feedback?**

While giving constructive advice, I often start to think from the receiver's perspective and would communicate in the way the receiver would want me to tell him. There could be instances when the receiver misunderstands the intent, in such a scenario I would ask the receiver about his understanding of the situation and would often remind him of his potential/strengths so that the receiver perceives it objectively and not subjectively. I also would give feedback through anecdotes, I would exemplify myself as being in the receiver's position to make the receiver understand that I empathize with him so that receiver takes the feedback seriously and not personally. I would prefer to receive the feedback the same way as above but me being on the receiver's end.

**3) What is your development style?**

I would definitely plan the design through discussions and functional overviews. But I wouldn't want to lay the complete plan and then start developing. Through the working style I have developed at my previous employers, I often tend to see things more clearly when I practicalize the ideas. During this whole phase, I often have a constant feedback loop with the Project Lead to understand the nitty-gritties to ensure that I'm on par with the expectations. Empiricalizing also helps me get a better picture and gives me more time to question the design. Hence I would try to build a proof of concept of the initial draft and see how things turn out to be.

## **The Task**

### **1) Describe the task you intend to work on.**

I intend to work on the Matrix exponentials task. One way to calculate the Exponential of a matrix is to use Taylor series expansion. We can plug in the matrix value in the Taylor series as we do for scalar values. But given that the Taylor series is an infinite series there is a trade-off on the precision of the required value vs computation of the value. The paper "Matrix Exponential using Scaling and Squaring Algorithm" (which I have tried to reproduce as a [POC](#)) addresses this issue very neatly. Firstly, an analysis has to be carried out on possible other approaches to this task and look at the performance numbers. For the Scaling and squaring algorithm, there were few more improvements (subcases) that had to be addressed to make this task more efficient. Eventually, this task has to be a distributed task. These provide a basic overview of the tasks at hand for this project, I will be addressing more on these in the Milestone section.

### **2) Why is this task exciting to you? What do you hope to learn?**

Matrix exponentials are used in solving systems of linear differential equations. It is also widely used in Quantum Mechanics (Schrodinger's equation: Describes the way a quantum particle behaves) and in Control Theory. I have been fascinated by the concept of Matrix exponentials right from the time I had the introduction in my Linear algebra course. The theoretical implications of the matrix exponentials have interested me very much. Firstly, this task interests me because, Though I had experimented with Uni-threaded applications in my undergraduate years, I never had a chance to implement a Multithreaded algorithm. The beauty of the vectorized concepts of Linear algebra offers us an opportunity to run the operations in parallel. Once we have the computational

graph, every cell in a matrix is independent of the other cell in the matrix and we can parallelize these operations for better runtime. Secondly, as part of the POC that I have developed for this project, I had a chance to go through the “Scaling and Squaring Algorithm” for matrix exponentiation. The technique (calculation of a pade estimate to categorize which pade value to be used) used in this implementation has interested me to pursue this project. I believe that I can extend this enthusiasm for the betterment of the community. I also hope to understand and achieve the parallelization (the true potential of Chapel) of the current task for efficient computation of matrix exponential and be challenged by the intricacies specific to the programming language.

## Milestones

1. Analysis
  - a. Research on the efficient approaches to calculating Matrix exponentiation
  - b. Can these algorithms be parallelized?
  - c. Implement the approaches
  - d. Performance test these implementations in a local environment
2. Since Matrix exponentiation involves the computation of matrices at multiple stages. Find a way to lazily compute the matrix products.
  - a. Research if we can have a robust computational graph to delay the computations as much as possible?
3. Find a way to further optimize the estimation of norm values.
  - a. A known way is to calculate the estimated norm values using an assumption that matrix entries are Bernoulli random variables.
  - b. Find alternative approaches if any.
4. Do the performance testing on the norm estimation algorithms. (These also have to be tested on how near are the predicted values to the actual values.)
5. Find an efficient way to compute Matrix exponential for Sparse Matrix.
6. Matrix exponential for the upper/lower triangular matrix can be computed more efficiently and has to be handled as a separate use case.
7. Matrix exponential eventually requires solving a system of linear equations. Need to figure out an efficient way to do this task.
8. The existing solve method (which solves for  $x$  given  $A \cdot x = B$ ) in Linear algebra only solves when  $B$  is a vector. Need to make this task compatible when  $B$  is a matrix (also make that efficient).



9. Need to make the whole setup working for a distributed environment.
10. Everywhere I have used the word “efficient” in the above tasks is inherently coupled with performance testing.
  - a. Need to performance test all the use cases and approaches.
  - b. Test on the edge cases.
11. Update existing and write new tests for all the developed features.
12. Documentation of all the above changes.

## Timeline

1. 20th April - 17th May :
  - a. Fixing bugs for Chapel.
2. 17th May - 31st May :
  - a. Community Bonding.
  - b. Getting familiar with the structure and code of Chapel.
3. 1st June - 15th June - **Milestone 1**
4. 15th June - 30th June - **Milestone 2,3,4**
5. 1st July - 10th July - **Milestone 5,6**
6. 10th July - 20th July - **Milestone 7,8**
7. 14th July - 2nd Aug - **Milestone 9**
8. 2nd Aug - 12th Aug - **Milestone 10,11,12**
9. 12th Aug - 15th Aug - **Contingency**
10. 16th Aug - **Final Evaluation**