Masters Of Aerospace Engineering
Research Project

GAUSSIAN PROCESS FOR STRUCTURAL ANALYSIS AND OPTIMIZATION

S2 Progress Report

Authors: Navpreet Kaur, Sneha Dwivedi

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Tutors: Prof. Joseph Morlier, Simone Coniglio

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1 Goal of the project

Gaussian process, usually considered in machine learning algorithms, is a process of deriving an approximate function by measuring the similarity between the sample points and then, interpolating the data on the non-sampling points and improving or optimizing the derived function. The approximate function is derived by using the statistical features of the data i.e., mean, median of the data points and the functions or kernels used for defining the similarity between the data points.[3] There are various kernels that are being used in the Gaussian process; the most common one is Square Exponential Kernel. Moving Least Squares(MLS) is one of the improved response surface method derived from the generalized or Weighted least squares to approximate the function locally rather than globally when there are local variations expected in the derived function.

The aim of the project to employ method of Moving Least Squares as a kernel function in the Gaussian Process that is a very unconventional approach to analyze and optimize a given structure. If this proposed method works effectively on comparison with the conventional methods, then it can be introduced as a new technique in defining engineering problems, example Machine Learning algorithms.

2 Project issues

The project demands a clear understanding of mathematical approaches and optimization techniques. Although there are many numerical tools available for the purpose of sleek analysis like Finite Element Method,[5] or GRENAT written in MATLAB, and the optimization techniques based on surrogate modeling like Efficient Global Optimization(EGO), Method of moving Asymptotes(MMA), we focus on to develop a new optimization technique using Moving Least Square as kernel in the Gaussian process. Moreover, they are required to be installed for the purpose of learning the tools more efficiently. Apart from the installation issues, the grip on MATLAB must be proficient in order to generate codes for the development of the Surrogate models and the optimization of the same.

There is no subsequent prerequisite available for our project and hence it becomes a challenge to start from the very basic and understand the rudimentary concepts. The bibliography available to us will be of substantial help and the access to GitHub will help us breaking down the complexity of the project into sub topics of our concern.

3 Main bibliography and State of the Art

With the pace the technology is developing, the engineering requirements are becoming more demanding in terms of design, accuracy, reliability, etc and to meet the same requirements, it is becoming difficult to perform the increasing number of simulations (time constraint as well as economic constraints). To alleviate this difficulty, surrogate models are evolving which are based on constructing an approximate model by taking into account only few of the computational simulations or by choosing the number of data points reasonably. The main bibliography will constitutes the work done on the Surrogate model and the Moving Least Square technique.[6] As mentioned in the Project issues, the project requires the fundamental concepts to be read first and hence the documents provided to us on Mesh less methods and Surrogate modeling will be the most essential ones in our path. Our research guide has been very diligent in providing us his MATLAB codes which will help us understand the basics. Our principal bibliography is the Surrogate modeling.[1] There will be a vast bibliography content which we are unable to mention right now being in the very early stage of the project.

4 Milestones of the project

Although a lot of time will be administered to the bibliography as we are at the very early stage of the project, but our aim is to complete the fundamental concepts by May. Moreover, the practical approach will go on simultaneously as we need to work on the programming tools and henceforth, the programming will keep going in parallel to every section of the project.

The time after this will be solemnly dedicated to understand the MATLAB codes provided by our research guide. This work is determined to be done by mid-June as we will be studying the structure of the code to inculcate the basic parameters and functions in ours. The test cases based upon the existing conventional methods will be presented during the S2 Project presentation. As from this point, the project is divided into two sections, it will be easier to complete the literature content of the individual topics. The individual tasks will be performed from the end of June and each's result will assists the other's outcome.

5 Task 1: Understanding of the Surrogate Models and the Gaussian Process

5.1 Description of Work

The nature of this task is completely literature based. As mentioned above, due to lack of pre-requisite bibliography for this project, it is readily important to have a strong hold of the background information on the Surrogate Models and how these models are defined using Gaussian Process.[2] We are not just constraint to literature survey for our understanding but our learning phase includes video tutorials on topics like, Kernel functions used in Gaussian process because sometimes it is difficult to comprehend the research text.

5.2 Plan versus achievements

We had already begun with our literature survey and the video tutorials. Even being an unconventional topic to work upon, we are at a slow pace to inculcate the fundamental concepts.

5.3 Changes to original plan

None.

5.4 Planned work for the next months

The next step is to identify the different types of kernels being used in Gaussian process and study the Moving Least squares method for implanting it as a kernel in the Gaussian Process.

6 Task 2: Understanding of Moving Least Squares Method and Surrogate Based Analysis and Optimization

6.1 Description of Work

After understanding the Task 1 key concepts, we will proceed to the next step of the literature review, understanding the concept of Moving Least Squares and exploring some of its applications using the numerical tools. During the same period, we will explore different techniques for Surrogate Based Analysis and Optimization as mentioned above.

7 Task 3: Training in MATLAB and FEM

7.1 Description of Work

MATLAB and FEM will be the substantial programming and analysis tools respectively for our project. MATLAB has been an integral part of our curriculum during the first semester and hence the concept is attainable. Similarly, FEM has been taught to us during our bachelors but we look forward to get deeper into both the tools for elaborate understanding. Our main aim is to comprehend the codes provided to us for which its readily required to understand the tools. We are taking aid from the online tutorials because it doesn't take much time whilst the literature might get complex at times. With time and concept clarification, the complexity of the problems will increase and we are keen to work upon them with the idea to attain enough background on the same.

7.2 Technical Progress

As mentioned earlier, both the tools are been introduced to us in our curriculum and we had been working on MATLAB for various modules in a confined manner. We have ran couple of codes provided to us by our guide.

7.3 Plan versus achievements

We are in parallel to the time planned for this task. The MATLAB and FEM learning will take a lot of time and its a continuous process of learning new varied things and hence we are looking forward to keep learning throughout our project timeline.

7.4 Changes to original plan

None as we are rooting to enhance our knowledge in the programming tools.

7.5 Planned work for the next months

For the upcoming months, we have planned to bring in use our pre defined knowledge in MATLAB and FEM and work on the test cases to obtain results. This will be done before the S2 Project presentation.

8 Task 4: Test Cases using conventional methods and our own developed method

8.1 Description of Work

In order to be progressive towards our project, our big step will be the application of the conventional methods on the Test Cases.[7] It will be the most important aspect of our project as we will be differentiating between the conventional and our non conventional methods of calculation to observe the effectiveness of the results obtained.

The project is divided into two sub parts. The optimization part will be carried out by Navpreet Kaur, wherein the analysis will be looked by Sneha Dwivedi. This phase of the project is yet to begin and require diligent and focused knowledge on the subject.

8.2 Technical Progress

In this phase, we will be developing our own Case Study, a new structure or a Sampling point. The focus will be upon the method that will be applied to the newly generated Sampling point and the results obtained through it.[8] The technicality aspect will completely rely upon MATLAB and FEM.

9 References

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