**Title**
Fast Fourier and Gauss Transforms as Fundamental Components of Fast Stencil Computations

**Abstract**
Looping kernels have long been the dominant approach to stencil computation algorithms, although they perform work linear in the size of the space-time grid being computed on. In this tutorial we will present a set of recent results on stencil computation algorithms which allow for large classes of linear stencils to be computed in sublinear work and much faster than has been possible with the previous state of the art. These new algorithms were discovered by exploiting theoretical connections between stencil computations, random walks, the discrete Fourier transform, and the Gauss transform. Finally, we will go over a publicly available stencil compiler which makes use of these new algorithms to generate asymptotically faster code than existing stencil compilers.

**Preferred duration (1.5 hours by default, 3h also available)**
3 hours.

**Outline of tutorial content and objectives with enough details for both the scope and the depth**
We will split the three hours into three talks:

1. Stencil computations using discrete Fourier Transforms (DFT) + experimental results
   **Objective**: To understand the connection between DFT, stencils on grids with periodic boundary conditions, and Fourier analysis on random walks, and how to extend the results to handle aperiodic boundary conditions..
   **Content**: We will go through the motivation, theory, and experimental results for a set of stencil computation algorithms based on DFT. Background is given on needed linear algebra, including diagonalization of circulant matrices and changes of basis. We specifically address periodic and dirichlet boundary conditions, and show how to generalize to rather large classes of linear stencils.
2. Stencil computations using the fast Gauss Transform (FGT) + experimental results
   **Objective**: To understand the connection between FGT, stencil on grids with free space boundary conditions, and the central limit theorem, and how to extend the results to handle periodic and the aperiodic Dirichlet boundary conditions..
   **Content**: We will go through the motivation, theory, and experimental results for a set of stencil computation algorithms based on FGT. Background is given on the necessary linear algebra, including diagonalization of covariance matrices and interpretation of eigenvectors as well as the central limit theorem. We specifically address free space, periodic, and Dirichlet boundary conditions.
3. Stencil Compiler
   **Objective**: To become familiar with the **FOURST** stencil compiler.
   **Content**: We will outline the automated code generation approach in FOURST, and describe its web interface and command-line tools to automatically generate efficient FFT-based stencil codes. We will explain how the generated codes can be linked with FFTW and Intel MKL.

**Prerequisite knowledge**
A general computer science background will be assumed.

**Very brief biography of the tutorial organizers and relevant information**

**Rezaul Chowdhury -** Associate Professor in the Department of Computer Science and the Institute for Advanced Computational Science (IACS) at Stony Brook University.
**Pramod Ganapathi -** Research Assistant Professor of Computer Science at Stony Brook University.
**Rathish Das -** Postdoctoral fellow in the Computer Science Department of the University of Waterloo.
**Zafar Ahmad -** PhD student in the Computer Science Department of Stony Brook University.
**Aaron Gregory -** PhD student in the Applied Mathematics and Statistics Department of Stony Brook University.
**Yimin Zhu -** PhD student in the Computer Science Department of Stony Brook University.