# Computations with Matrices and Polynomials:

# Algebraic and Numerical Algorithms on

# Serial and Parallel Computers

**SPRING 2020 Code [92312], 3 credits**

**Fridays, 2.00 – 4.00 p.m. (tentative), Room TBA;**

**Victor Pan, Distinguished Professor, Fellow of the American Math. Society (designated for ``Contributions to the Mathematical Theory of Computation" in 2013)**

**Rationale**

Algebraic and Numerical Algorithms, and in particular matrix and polynomial algorithms, are the backbone of the modern computations in Sciences, Engineering, and Signal and Image Processing, routinely invoked when one turns on computer, TV or radio. The subjects are studied in Computer Science, Data Mining and Analysis, and Computational Mathematics.

The course will introduce the students to some most fundamental methods and techniques, will provide insights into the fields, and some experience in the design, analysis and implementation of modern algorithms.

It can lead students to participation in research currently supported by the Instructor's two NSF Grants (over $1,000,000 overall), to publications in Journals and Refereed Proceedings of Conferences, and to the defenses of PhD Theses. The Instructor has mentored 24 defenses so far; 3 defenses are expected for Spring 2020; some of his former students are Professors of Computer Science at

the Graduate Center of CUNY and CUNY Colleges; some other ones have highly paid positions in Industry.

**Description**

The course will cover some fundamental topics in matrix and polynomial computations with extension to Data Science. The instructor has decades-long experience of teaching and doing research on these subjects, covered in his 4 books and about 300 refereed publications. The course has no prerequisites.

**Topic List**

- General matrices, their factorizations, norms and other basic concepts and techniques
- Low Rank Approximation of matrices
- Linear Least Squares Regression
- Computations with data sparse matrices such as Toeplitz, Hankel, circulant and HSS matrices
- Fast Fourier transform and link to computations with polynomials
- Data compression by using matrix structures
- Basic operations of computer algebra
- Randomization methods for matrix and polynomial computations

The topics are sufficient for a two semester course, but Instructor plans to adjust the study to students' and Department's interests. For example, he can devote more time and attention to matrix rather than polynomial computations and can focus on some selected areas such as Low Rank Approximation of matrices and Linear Least Squares Regression, which are the subjects of his most recent research interests and publications and which have extensive applications to Data Science.

The instructor will be happy to guide independent study of related topics of students' interest not covered in the course.

In the past, when the class was full to its 12-student limitation, the Instructor guided the students for their independent studies and credits. He can do this again.

**Leaning Goals**

Students are expected to

- understand the basic principles, concepts and techniques of symbolic and numerical computations with general and data sparse matrices and with polynomials
- learn some fundamentals of Low Rank Approximation of matrices and Linear Least Squares Regression
- learn some selected matrix compression techniques
- learn efficient algorithms for the most popular operations with polynomials, rational functions, and general and data sparse matrices
- get a chance to advance in research, publications and preparation to PhD defense based on the course study

**Assessment**

- Class participations and discussions will be used to evaluate students' understanding of concepts of algebraic and numerical computations. The attendance and participation account for 10% of the final grade
- Homework assignments (40% of the final grade) will be designed to provide the opportunities for students to verify their understanding of the current subjects of the study and their ability to employ the relevant techniques and algorithms introduced for Algebraic and Numerical Computing
- Final and possibly midterm tests will represent 50% of the final grade. They will give students chances to show their overall understanding of the course subjects
- The students’ advances in research and implementation of recent and new algorithms can demonstrate their knowledge and understanding of the course materials. This can be counted as partial substitution for homework and exams towards the final grade.