Title: **Signal Processing for Mass Testing in Fighting a Pandemic: A Sampling Theory Perspective**

Duration: Half-day (3 hours)

Presenters (in alphabetical order by last name):

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Summary:
The COVID-19 pandemic has caused significant damage to human society. Mass testing is vital in fighting against the ongoing or any future pandemic. However, testing capacity is often limited, with shortage of testing facilities and reagents. These tests can also be slow, costly, heterogenous, and even inaccurate.

In this tutorial, we view mass testing from a sampling theory perspective, and introduce recent advances in signal processing theories/methods to expand test capacity, reduce test cost, and increase test reliability. These include novel compressed sensing methods for virus testing using quantitative Polymerase Chain Reaction (qPCR) machines for increasing test throughput and reducing test cost, possibly further aided by use of family-based or contact-trace based side information; novel error correction signal processing methods to improve test reliability; and optimal allocations of testing (sampling) resources in different communities to best contain disease spread through exploration-exploitation trade-off in testing.

We will provide system modelling, algorithm designs, and performance analysis for these methods, and develop the underlying mathematical theories. We will demonstrate the impacts of these methods on real clinical applications, before introducing open research questions inspired by clinical constraints/applications, and future research directions. The audience will be exposed to state-of-the-art analytical and software tools for matrix design, decoding algorithms and analysis of group testing/compressed sensing, and sequential decisions in mass testing. This tutorial will not only demonstrate the power of signal processing methods in fighting the pandemic, but also develop novel signal processing theories and methods and introduce intellectually-inspiring fundamental research questions.

Outline:
We divide the talks into 8 sections.

1) Background on COVID-19 Pandemic.

We will review background knowledge on the COVID-19 pandemic and explain the importance of testing.

2) Background on the physics, chemistry, and biological aspects of testing technologies for COVID-19, especially for the widely used quantitative Polymerase Chain Reaction (qPCR) machines.

We will review related background knowledge, laying foundations for problem formulations that follow.

3) Qualitative group testing methods for increasing test throughput.

In this section, we will introduce state-of-the-art results on group testing, and review advances on designing group testing for increasing test throughput.

4) Novel quantitative compressed sensing inspired methods for increasing test throughput

In this section, we will introduce novel compressed sensing methods for qPCR to greatly boost its testing capacity, reduce chemical-reagent consumption, and reduce testing cost. This includes a) signal modelling b) sensing matrix design; c) decoding algorithms; d) performance analysis. We show how to use side-information to potentially improve the performance of these algorithms using family-based or contact trace based side information.

5) Novel signal processing methods to increase test reliability.

In this section, we will introduce novel signal processing approaches via pooling which surprisingly increases test reliability, and introduce related theories.

6) Optimal allocations of testing resources in different communities to best contain disease spread through best exploration-exploitation trade-off in testing.

In this section, we describe a sequential decision, and learning based framework to optimally allocate testing resources in different communities through an optimal exploration (surveillance testing to discover new spread)-exploitation (diagnostic testing) trade-off.

7) Experimental Validations and Clinical Applications

In this section, we will survey and introduce results on experimental validations and clinical impacts of these approaches.

8) Open questions, and future research directions.