**1. Short Title:** Advanced Discrete-Event Simulations in R

**2. Teaching Team:**

1. Thomas A. Trikalinos, Brown University.
2. Fernando Alarid-Escudero, Stanford University.
3. Yuliia Sereda, Brown University.
4. Stavroula A. Chrysanthopoulou, Brown University.

**3. COI:**

1. No conflicts to disclose.
2. The examples use the publicly available **nhppp** R package which is developed by the course instructors

**4. Course Style:** Workshop. We will review just enough theory to justify intuitions for several clever tricks – but the emphasis is on a hands-on implementation.

**5. Proposed Course Length:** Half day.

**6. Course Level:** Advanced.

**7. Proposal Structure:**

*Course Descriptive:*

A discrete event simulation (DES) stitches together several elemental mathematical models, each describing the occurrence of different events. For example, in a DES of a cancer's natural history, a person may (i) develop zero, one, or more tumors; each tumor may (ii) become malignant and (iii) give symptoms; (iv) symptoms can lead to diagnosis; and death from (v) cancer or (vi) non-cancer causes may occur. Each type of events (i) to (vi), is described by a mathematical object called a point process. Thus, the central task in a DES is simulating point processes in which the rate of event occurrence varies with time.

A widely used model for point processes with time-varying intensity functions is the nonhomogeneous Poisson point process (NHPPP). NHPPPs are satisfactory models for many phenomena and thus are commonly used in DES applications. If you can use an NHPPP to describe a point process, get a lot of flexibility: Any measurable non-negative bounded function can be used as an intensity function – so, have at it.

In this course, we will abstract DES to the level of sampling from NHPPPs, discuss how to sample from NHPPPs accurately and efficiently, and then tie everything together in a hands-on example that simulates a cancer's natural history.

*Learning Objectives:*

By the end of the course, participants will be able to discuss:

- Just enough theory to motivate three properties of NHPPPs (memorylessness, composability, and transmutation by transforming the time axis) that are important for simulation because they enable exact sampling and justify some clever tricks.

- Algorithms to sample event times exactly, fast, and with a small memory footprint, and their implementation with the **nhppp** R package.
- How to do conditional simulations, such as simulating only those diagnosed with cancer at some point in their lives, by a specific age, or at a specific age.
- How to structure the code of a basic DES.

*Prerequisites:*

- Some familiarity with DES (what it is, why it is useful).
- Some familiarity with programming in R.
- A computer with an R installation (version >= 4.0.0), and the most recent versions of the **nhppp** and **data.table** R packages from the Comprehensive R Archive Network (CRAN), at least for those who wish to follow the exercise during the course.
- (Some familiarity with basic calculus is helpful but not required.)

*Time Allocation and Topic Outline:*

(The proposed outline takes 3.5 hours with one 15-minute break about at the midpoint. The number and length of breaks are to be determined by the conference.)

[10 min] Introductions and administrivia

[20 min] DES as a composition of point processes: (i) What is a DES; (ii) gentle introduction to one-dimensional point processes; (iii) NHPPPs are often a good choice.

[20 min] NHPPPs -- properties that allow for fast sampling and clever tricks

[30 min] Sampling algorithms and the **nhppp** R package.

[15 min] Break

[90 min] Guided exercise: Implement a simple cancer natural history DES, demonstrating

(i) unconditional sampling of events in a time interval,

(ii) sampling conditional on the number of events (e.g., exactly one, at least one) in an interval, and

(iii) sampling conditional on downstream events (e.g., to simulate patients diagnosed in each SEER year).

[10 min] Advanced Topic Teaser on self-excitatory processes: point processes that are not NHPPPs and when you may need them:

[15 min] General Q&A

**8. Faculty Background & Qualifications**

1. Thomas A. Trikalinos, MD, is Professor of Health Services, Policy & Practice and of Biostatistics at the Brown School of Public Health. He works on evidence synthesis and health decision making.
2. Fernando Alarid-Escudero, PhD, is an Assistant Professor of Health Policy at the Stanford University School of Medicine. He works on methods and applications of mathematical and statistical modeling in health.

3. Yuliia Sereda, PhD, is a Researcher at Brown University. She works on mathematical modeling of cancers.
4. Stavroula A. Chrysanthopoulou, PhD, is an Assistant Professor of Biostatistics at Brown University. She works on methods for discrete event simulation and microsimulation models.