# Master Class - Deterministic Dynamics, Machine Learning & Tipping Points


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Theme Lead


**Theme 2**
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Deterministic dynamical systems include any physical system which behave in a predictable way. We can measure time series from these systems and use these to build a model of the behaviour of the system. An example might include a mechanical pump during normal operation from which we make measurements of axial vibration and fluid flow.
Using these time series measurements, we can construct a mathematical model of the dynamical model of the behaviour of the system. The tools we use to build these models are techniques from machine learning, and then this model acts as a simulation of the system (a so-called "digital twin").
We can compare the future behaviour of the model to observed behaviour of the system - when these two things differ, they differ because the real physical system is no longer performing in the same regime. For example, the mechanical pump may begin to cavitate and vibrate more strongly (a simple example which could also be observed with less sophisticated techniques). Often this change in behaviour can be characterised as a tipping point (hysteresis and climate change /warming are both examples of tipping point behaviour). Mathematical techniques can then be applied to these models to predict imminent nascent tipping.

The master classes will provide a broad introduction to the fields of applied dynamical systems, recurrence quantification analysis and complex net- works. We will discuss the computational tools that can be derived from these methods to analyse time-series data.

Participants will be able to incorporate these computational tools to their feature extraction framework as a complementary/alternative to traditional feature extraction techniques.

We will also review some of the transition (change-point) detection methods derived from the above techniques. They are useful to track changes in the behaviour of time-series.

Participants will be able to implement these change- point detection techniques in asset's health-monitoring signals to enhance the predictive analysis performances.