# JIDT: An information-theoretic toolkit for studying the dynamics of complex systems

Joseph T. Lizier

Tutorial at IEEE SSCI 2017, Honolulu

8:30am, Monday November 27, 2017

Complex systems are increasingly being viewed as distributed information processing systems, particularly in Artificial Life, machine learning, computational neuroscience and bioinformatics. This trend has resulted in a strong uptake of information-theoretic measures to analyse the dynamics of complex systems in these fields.

This tutorial will briefly review the use of these measures as applied to complex systems, and then introduce participants to a software toolkit for conducting such analysis on empirical data – JIDT [1]. JIDT provides a standalone, (GNU GPL v3) open-source code implementation of measures for information dynamics, i.e. measures to quantify information storage, transfer and modification, and the dynamics of these operations in space and time. In addition to basic information-theoretic measures, principally the toolkit implements the transfer entropy, (conditional) mutual information and active information storage, for both discrete and continuous-valued data. Various types of estimators (e.g. Gaussian, Kraskov-Stoegbauer-Grassberger) are provided for each measure. Furthermore, while written in Java, the toolkit can be used directly in Matlab/Octave, Python and other languages, and it also provides a GUI "AutoAnalyser" for point-and-click computation as well as code-template generation.

**Learning outcomes:** Participants will gain an understanding of how the toolkit functions, how to install and run the software in their chosen environment, and see more complex demonstrations, e.g. analysing information dynamics of cellular automata. Specifically, participants will learn:

- background on the information-theoretic measures implemented in JIDT;
- how to use the JIDT AutoAnalyser GUI demo to run analysis *without writing code*;
- how to extend code templates generated with the AutoAnalyser for more complex analysis; and
- where to seek further support information on JIDT.

**Preparation:** To fully engage with the software toolkit, participants *should bring their own laptop*, download the toolbox in advance, and prepare your choice of *one* of the following environments:

- To use Matlab (*preferred*), simply a Matlab installation (or alternatively Octave);
- To use Java, a Java SE / JDK installed;
- To use Python, a Java SE / JDK installed, and the Python jpype and numpy packages (see our wiki for more details). We will not have time on the day to support installation of these dependencies.

Resources for the tutorial (slides, activities) will be posted on the JIDT wiki.

[1] J. T. Lizier. JIDT: An Information-Theoretic toolkit for studying the dynamics of complex systems. *Frontiers in Robotics and AI*, 1:11+, 2014. doi:10.3389/frobt.2014.00011, arXiv:1408.3270

**Bio of presenter**

Dr. Joseph Lizier is an ARC DECRA fellow, and Senior Lecturer in Complex Systems, in the Faculty of Engineering and IT at The University of Sydney (since 2015). His research focusses on studying the dynamics of information processing in biological and bio-inspired complex systems and networks, in particular for neural systems. He is the primary developer of the JIDT toolbox for measuring the dynamics of complex systems using information theory, and is contributing to the related IDTxl toolbox for inferring effective network structure in neural data. He has co-authored 60 research articles, focussing on the use of information-theoretic measures to analyse complex systems, including the recent book "*An Introduction to Transfer Entropy: Information Flow in Complex Systems*" (Springer, 2016), and his work has attracted several awards including Best Paper at IEEE ALife in 2011 and 2013. Before joining The University of Sydney, Dr. Lizier was a Research Scientist and Postdoctoral Fellow at CSIRO ICT Centre (Sydney, 2012-14), and a Postdoctoral Researcher at the Max Planck Institute for Mathematics in the Sciences (Leipzig, 2010-12). He has also previously worked as a Research Engineer in the telecommunications industry, including at Seeker Wireless (2006-2010) and Telstra Research Laboratories (2001-2006). He obtained a PhD in Computer Science (2010), and Bachelor degrees in Electrical Engineering (2001, with University Medal) and Science (1999), from The University of Sydney.