Simulating branching processes via a size constrained particle system

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Branching processes naturally arise as pertinent models in population size dynamics, nuclear fission, genetic dynamics, growth-fragmentation processes and cell proliferation kinetics. Further, in a wide variety of situations, it can be shown that branching processes exhibit a Perron Frobenius type behaviour, that is, when normalised by the average growth of the system, the first moment of the branching process converges to a stationary distribution. Thus, efficiently estimating the growth rate and stationary distribution is imperative to understanding the leading order behaviour of the system.

Recently, Cox, Horton and Villemonais have developed a resampling and selection model [1] that allows one to simulate branching processes and estimate such quantities, while keeping control over the population size. Roughly speaking, particles evolve according to a branching process until either the number of particles becomes too high or too low, in which case particles are either removed (selection) from the system or duplicated (resampling), respectively.

The objective of this master's project would be to explore some of the possible extensions of this model. For example, the current model only allows for binary branching and so a natural direction would be to allow more general branching distributions to allow one to consider a wider variety of processes. Another avenue would be to try to allow the branching and killing rates to depend (in a measurable way) on the past of the particle system, in order to reduce the number of selection and resampling events in the future. The student would also be expected to develop numerical models to simulate the particle system in particular situations.

The master's project would take place in Nancy, at IECL University of Lorraine.

This master's project is intended to be continued by a PhD Thesis in Bordeaux and Nancy, under the co-supervision of Emma Horton (CR INRIA, Bordeaux) and Denis Villemonais (Teacher Assistant, Nancy). This work is part of a collaboration with Alexander Cox, Professor in Bath, UK.

References

[1] Cox, A. M., Horton, E., & Villemonais, D. (2022). Binary branching processes with Moran type interactions. arXiv preprint arXiv:2207.03323.