Cortix: An Open Source Framework For Dynamic Network Simulations at Scale

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I. Introduction

With the advent of scientific computing comes a wealth of computational models produced by the scientific community at large. From molecular dynamics to evolutionary systems, such models are typically developed independently, with varied programming strategies, data formats, and time scales in an effort to address a domain-specific question.

As such, we present **Cortix** (cortix.org) - an open source Python library for system-level module coupling, execution, and analysis. Cortix provides an environment for constructing a network of computational modules through a unified framework. To facilitate communication within this network, Cortix implements a protocol for communication between modules, allowing them to send and receive data from other modules as the overall simulation evolves.

II. Droplet Vortex Model

This Cortix use-case simulates the motion of a swarm of droplets in a vortex stream. It consists of two modules, namely, a `Droplet` module used to model the droplet dynamics, and a `Vortex` module used to model the effects of the surrounding air on the falling droplets. The `Droplet` module is instantiated as many times as there are droplets in the simulation while a single `Vortex` module is connected to all `Droplet` instances. The communication between modules entails a two-way data exchange between the `Vortex` module and the `Droplet` modules, where `Droplet` sends its position to `Vortex` and `Vortex` returns the air velocity to `Droplet` at the given position.

III. Results

A set of 1000 droplets of water (`Droplet` modules) are released from 500-m altitude into a `Vortex` stream of air at random positions within a square area of 250×250 m^2 and random droplet diameter sizes ranging from 5 mm to 8 mm; standard physical properties of both fluids are used.

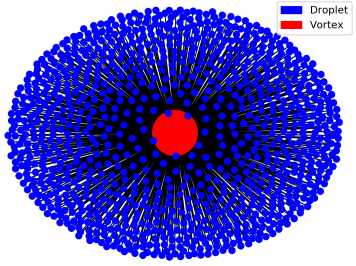

Fig. 1. Cortix connectivity network for 1000 `Droplet` instances and one `Vortex` module.

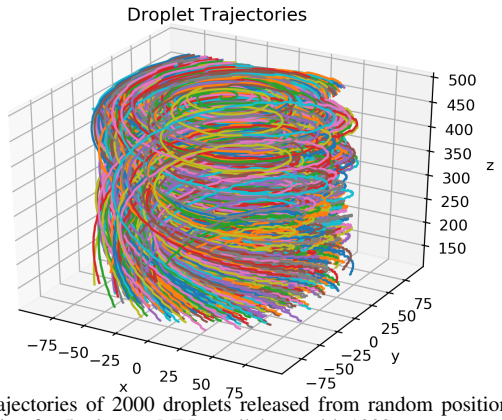

Fig. 2. Trajectories of 2000 droplets released from random positions at 500-m altitude falling for 5 minutes. MPI parallel run with 1003 processes corresponding to 1000 `Droplet` modules, 1 `Vortex` module, 1 `DataPlot` module, and 1 Cortix master process.

This droplet swirl example tests the parallel scalability of Cortix to connect over 1000 modules, as well as the multiple instantiation of the same module aimed at simulating the collective phenomena of rainfall. Future work will focus on Cortix module development to build models of complex dynamical systems as applied to various scientific areas.

As shown in table 1, adding more droplets to the simulation, increased running time. The communication bottleneck of one-to-all modules can be seen from the fact that the performance trend is not linear in particular above 1000 processes.

Number of Droplets	Execution time (s)	# of proc. cores
250	127	252
500	168	502
1000	346	1002
2000	1660	2002

TABLE I
Droplet Simulation Performance Trend

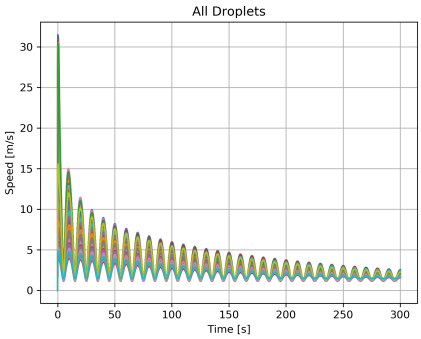

Fig. 3. Speed of all droplets varying with time showing the approach to terminal velocity.