Marco Bozza

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Education

Current Position: PhD student in mathematics at University of Trento in collaboration with COSBI (The Microsoft Research Centre for Computational and Systems Biology). — Trento, Italia
Supervisor: Luca Marchetti, Stefano Giampiccolo. — *2025 - ...*
Co-Advisor: Simone Pezzuto.

Master Degree: final grade: 110/110 cum Laude. — Torino, Italia
Weighted grade average: 29.31/30.
Thesis's Title: Topological and Computational Aspects of the Kuramoto Model — *2021-2024*
Advisor: Paolo Cermelli, Federica Galluzzi

Bachelor Degree: final grade: 110/110 cum Laude. — Ferrara, Italia
Weighted grade average: 29.4/30.
Thesis's Title: Hilbert's function for a set of points in $\mathbb{P}^2$ — *2018-2021*
Advisor: Philippe Ellia

Research Projects

I am currently working on two distinct research projects:

- **Mode Connectivity in Neural Ordinary Differential Equations**: Recent works has shown that independently trained models in modern deep-learning architectures, like transformers, GNNs, CNNs, and ResNets, can often be connected by low, or even near-zero loss paths, despite appearing to lie in distinct loss basins [1], [2], [3]. This phenomenon is largely attributed to overparameterization and the resulting symmetries in parameter space (e.g., neuron permutations) [4], [5]. Neural Ordinary Differential Equations (NODE) learn a continuous-time vector field parameterized by a neural network, trained by integrating the ODE and minimizing a task loss on the resulting trajectory [6]. We have empirically observed mode connectivity in NODE as well, and our current goal is to relate these connectivity properties to Lie symmetries of the learned vector field.
- **Surrogates Models**: In parallel I'm working on the generation of Virtual Population using surrogates model. While there is not yet a universally agreed definition of a VPop in QSP [7], the core problem can be stated as follows: consider a model $M = M(\theta)$ depending on parameters that defines a system $\mathbf{y} = M(\theta; \mathbf{x})$. In practice, we are often interested in a derived quantity $\mathbf{z} = g(\mathbf{y})$ for which experimental or clinical data are available. Virtual population generation consists of identifying a set (or distribution) of parameter θ such that the induced model outputs reproduce the observed distribution of $\mathbf{z}$. A common challenge in QSP is that models are *underdetermined*, meaning many (often infinitely many) parameter sets can match the same observables, so additional criteria are needed to select parameter sets that remain biologically plausible. Existing QSP methods address this selection problem [8], [9], [10]; my current work extends these approaches by using a surrogate for the map $\theta \mapsto g(M(\theta; \mathbf{x}))$ to accelerate VPop generation, and by quantifying the trade-off between surrogate speed and the accuracy of the resulting virtual population.

Master Thesis

During my Master's thesis, I implemented and analyzed the Kuramoto model on graphs generated via the Stochastic Block Model. Under the supervision of Professors Paolo Cermelli and Federica Galluzzi, I investigated the synchronization phenomenon using two techniques that, in this context, had not previously been explored. After numerically integrating the model, I used Time-Delay Embedding (TDE) to map the time series into geometric structures, and then analyzed their topological properties through Persistent Homology. I observed that the resulting persistence diagrams reflected the community structure of the underlying graph. More generally, I showed that these techniques are sensitive to the onset of synchronization.

References

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