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COLNA: A Python Package to Analyze Complex, Linear Networks

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Summary

The complex linear network analyzer (COLNA) python package analytically computes the propagation of complex valued signals in networks with linear nodes and directed, complex valued and delayed edges (Fig. 1). COLNA offers an easy and well documented interface, which allows to quickly build network models and understand their behaviour. Its main purpose is to compute coherent wave propagation through linear photonic circuits, but COLNA might be useful in any research area, where signal propagation through linear complex networks is of practical relevance.

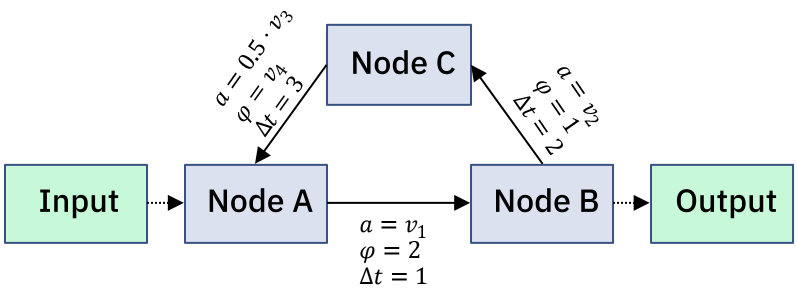

Figure 1: Example of a recurrent network with three nodes that can be modelled using COLNA. The edge parameters (a, φ and Δt) can be numeric or symbolic numbers (variables).

Functionality and Features

Fig. 2 illustrates the core functionality of COLNA. Networks are assembled by adding nodes and edges. To verify the assembly, networks can be visualized as a graph. In a next step, COLNA computes all paths leading from input to output nodes, including recurrent paths, down to a certain amplitude accuracy threshold. It supports the mixed use of numeric and symbolic numbers (variables) for all edge properties, returning either a numeric or analytic description of the waves' phase and amplitude at the output nodes. Testbenches provide functionality to inject complex valued signals to the network and compute the resulting signals at the output nodes.

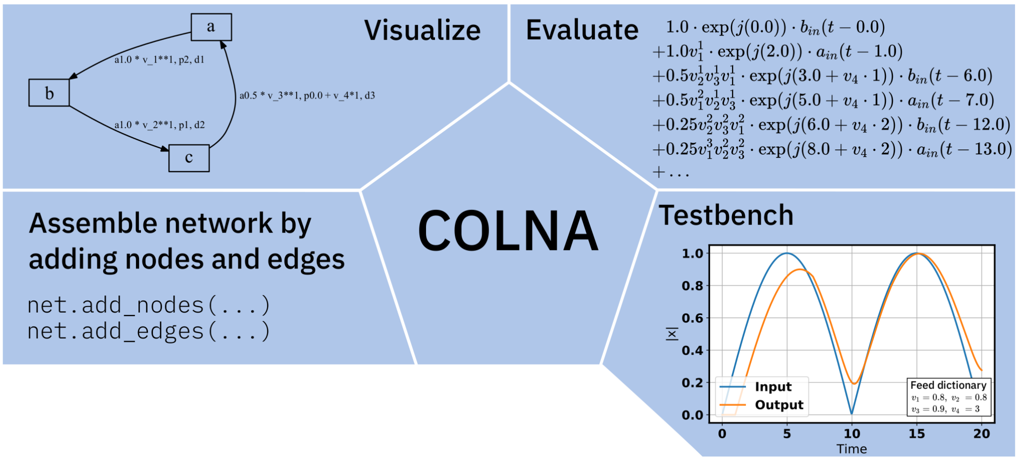

Figure 2: Illustration of COLNA's core functions. Assembly and visualization of complex valued networks, evaluation of the wave propagation from input to output nodes. A testbench injects signals to the network and records the signals at the output nodes.

Statement of Need and Commercial Alternatives

Today, integrated Si photonic circuits (PIC) cover a large range of functionality, from optical interconnects (Pavesi & Lockwood, 2016) to neuromorphic computing (Vandoorne et al., 2014) and sensing applications (Bogaerts et al., 2012). COLNA makes it possible to model such systems and provides an analytic expression of the systems transfer matrix. The analytic expression is often useful to better understand the effect of system parameters' (i.e. edge parameters) variation on the output signal. With its simple interface COLNA is also well suited for educational purposes, where analytic expression help to better understand the functionality of simple photonic networks, like for example a Mach-Zehnder interferometer. Commercial alternatives to model photonic circuits include for example Lumerical Intereconnect (Lumerical Inc., 2020) or Caphe (Fiers et al., 2012), which both simulate the signal propagation through photonic systems using time- and frequency domain methods. In contrast to COLNA they support non-linear components, but do not provide an analytic description of the network.

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