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CRIREL: A Hyperflexible and Reconfigurable Neural Circuit

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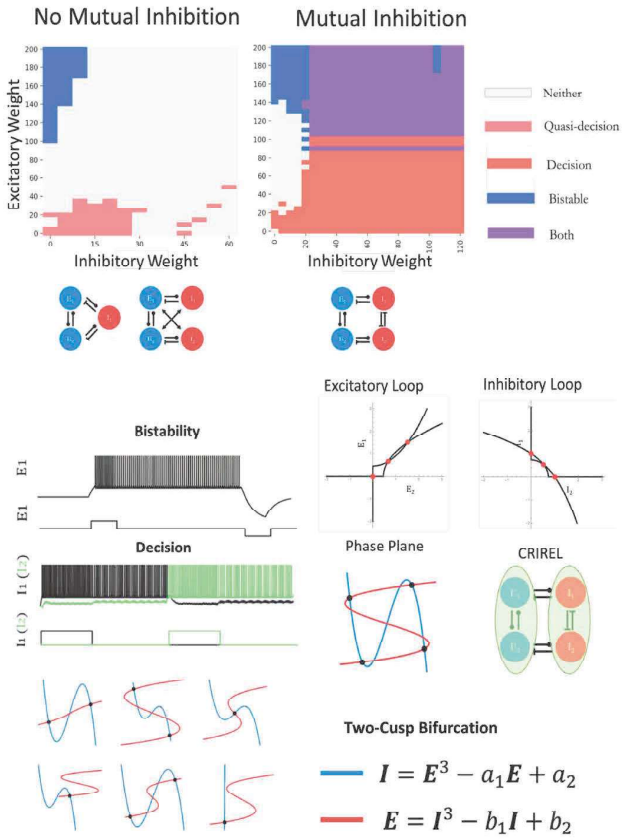
Abstract

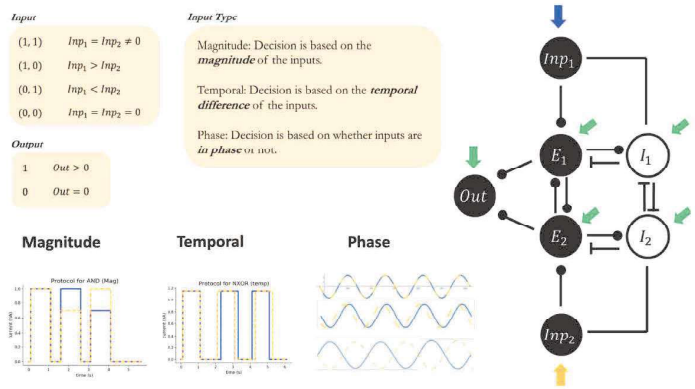
- **Recurrent Network Flexibility & Reconfigurability**: Recurrent networks near bifurcations enable flexible switching of behavior based on context without modifying synaptic weights.
- **CRIREL Circuit Model**: A 4-neuron circuit (CRIREL) demonstrates flexibility by encoding 24 functions using fixed weights, with bifurcation control achieved through varying bias currents.
- **Logic Operations & Event-Driven Computing**: The circuit performs 8 logic operations (e.g., AND, XOR) influenced by input magnitude, timing, and phase, enabling event-driven computation.
- **Applications:** Demonstrates lower gate count and reconfigurable gates in a full adder and motion detecting circuit.
- **Dynamic Reconfiguration of Multilayered Logic**: Reconfigurability and flexibility still possible in downstream logic even for event-based logic gates.

Mutual Inhibition Expands Functionality



- Adding mutual inhibition to a circuit allows it to simultaneously perform decisions and bistability.
- We call these circuits Coupled Recurrent Inhibitory Recurrent Excitatory Loops (CRIRELs).
- Inhibitory loops add cusp bifurcations.
- This expands the functionality of the network by offloading decision into the inhibitory network

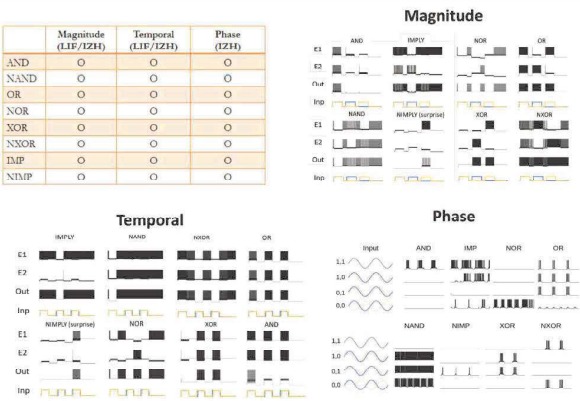
Flexible Transitions Using Bias Currents



- Using just bias current can we switch between functions.
- $C\frac{dV}{dt} = -g_L(V - E_L) + I_b$
- A circuit is flexible if its functional mode is easy to switch.
- We can switch a CRIREL's function simply by changing its bias current, leaving synaptic weights unchanged.
- We show this for a set of logic functions with three different input types: magnitude, temporal, and phase.

24 Different functions coexist in one circuit

	Magnitude (LIF/IZH)	Temporal (LIF/IZH)	Phase (IZH)
AND	O	O	O
NAND	O	O	O
OR	O	O	O
NOR	O	O	O
XOR	O	O	O
NXOR	O	O	O
IMP	O	O	O
NIMP	O	O	O



- We are able to reproduce 24 different logic-like functions for one single CRIREL circuit.
- All 24 functions have the **same** synaptic weight.
- Only the bias current change.
- We test this with two different model neurons, leaky integrate-and-fire neurons, and Izhikevich neurons (not shown; see paper).