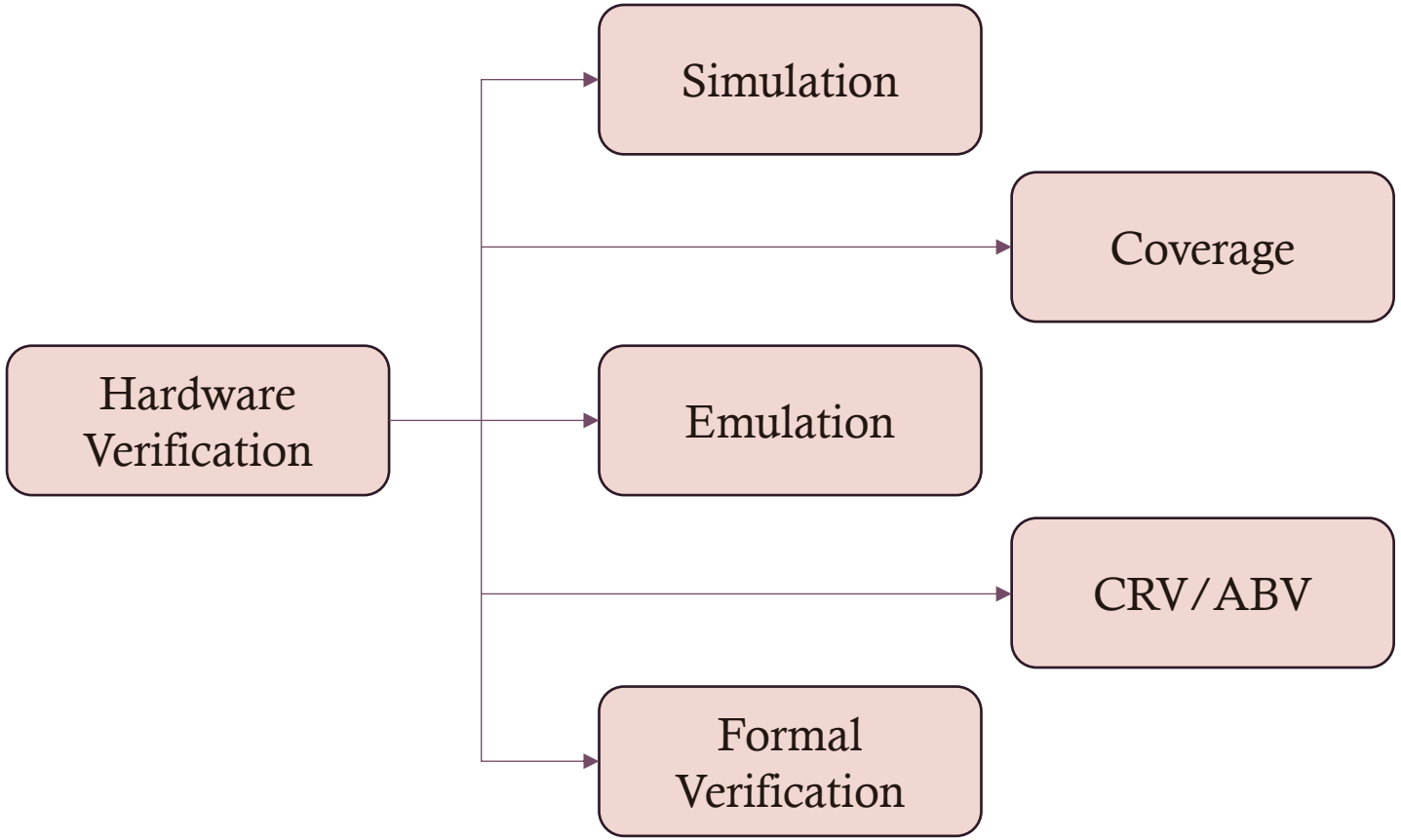
Using Genetic Algorithms to Discover Cause-and-Effect Relationships in Hardware Signals

AUTOMATED HARDWARE VERIFICATION WITH GENETIC ALGORITHMS AND VCD ANALYSIS

Hardik Raina

Agnisys

THE STATUS QUO



THE PROPOSAL

Motivation for using Genetic Algorithms

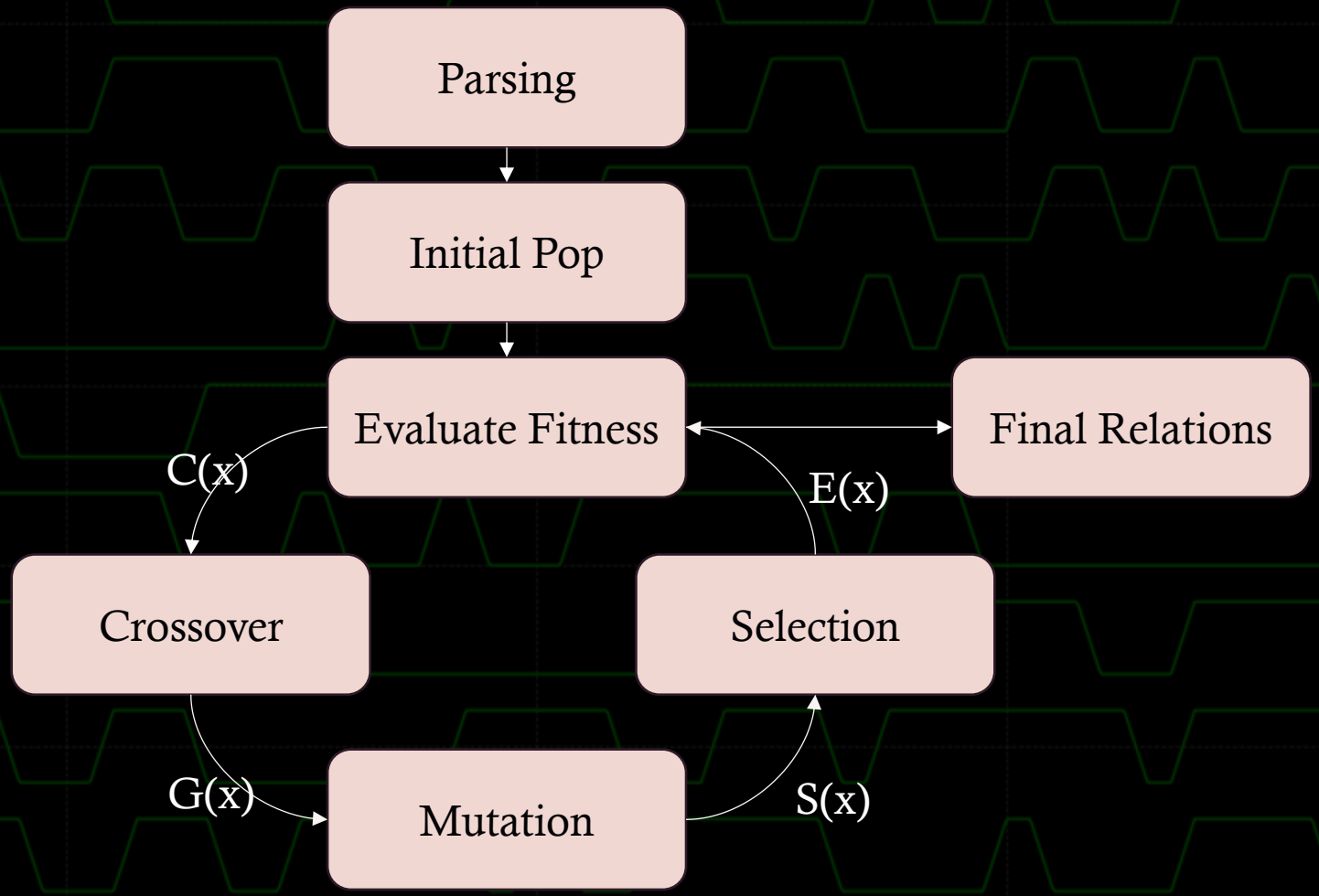
GA's are effective in scenarios where we can't simply brute-force every possible solution, which is perfect for exploring potential signal relationships.

The aim being to bring down the exponential problem space into a linearly solvable space by evolving heuristics based on the patterns observed in the data.

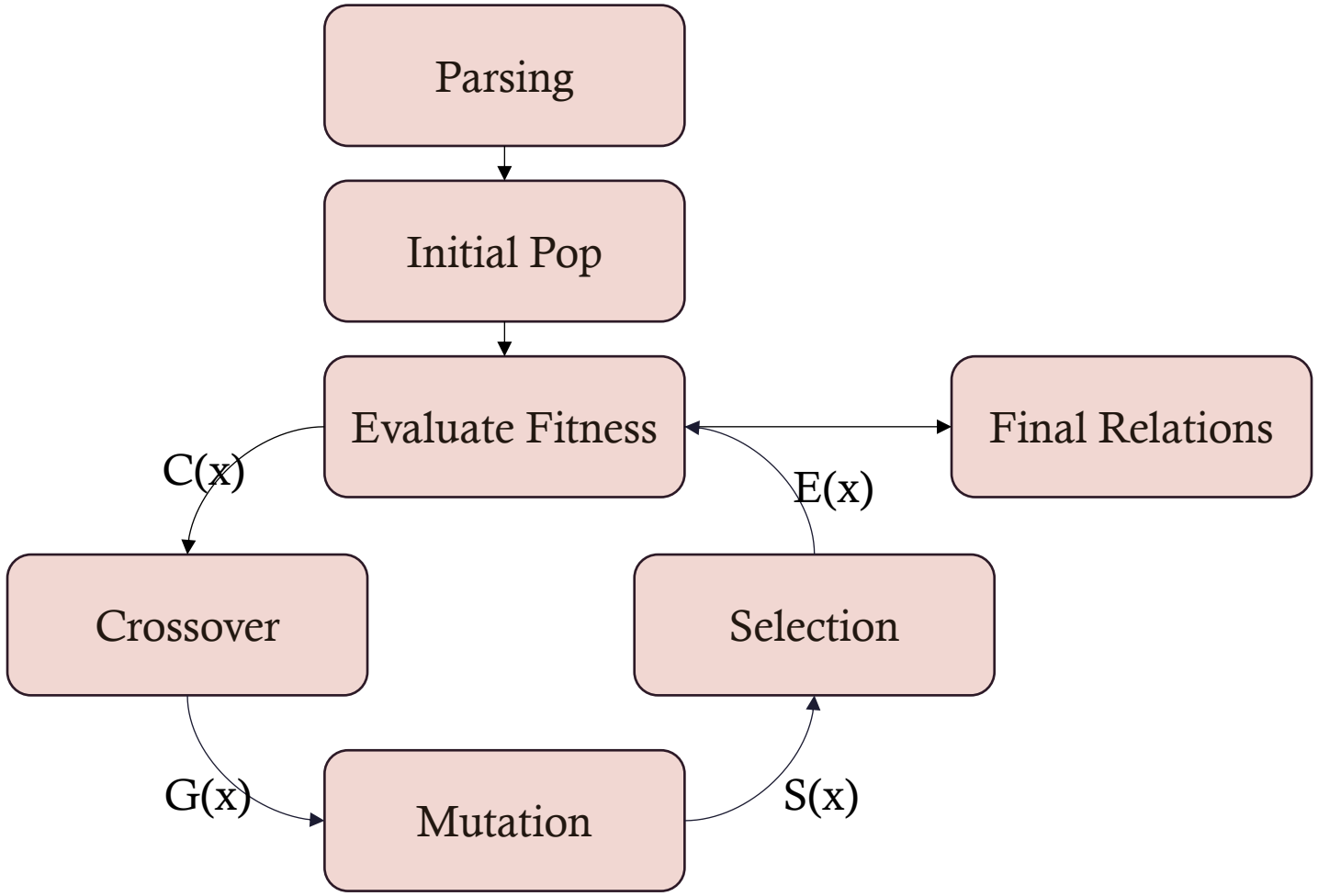
VCD

A measure of change with respect to time of each signal in tandem. Capturing the timing and states of various signals, helping engineers analyze and debug hardware behavior.

FRAMEWORK OVERVIEW

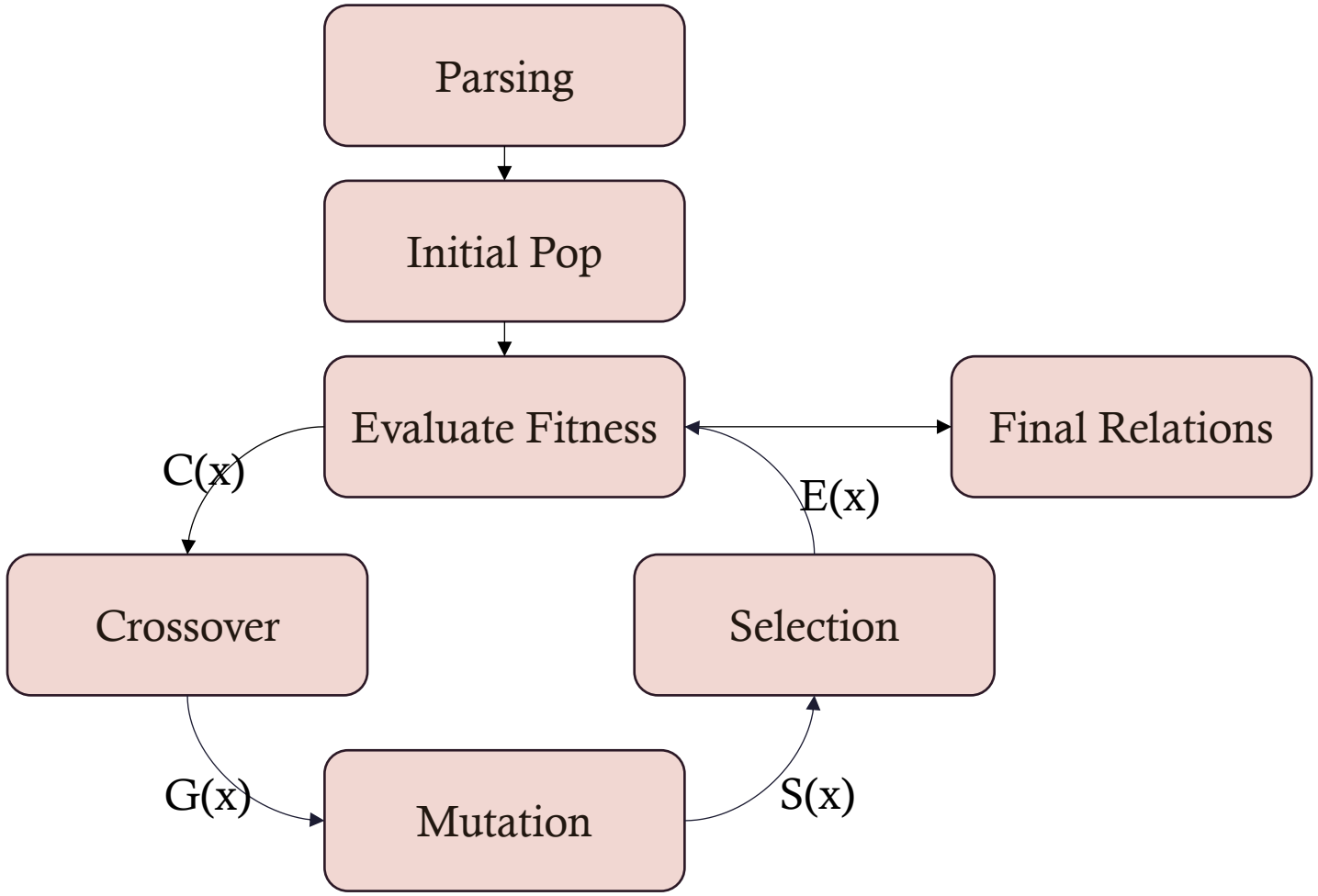


The Parsing



One of the primary requirements for GAs and Artificial Intelligence in general is a need for a degree of uniformity in the data.

Thus while parsing, one of our first steps is to restructure the data to hold uniform timestamps while still retaining all the relevant information so captured in the VCD File.



The Initial Population & Fitness Evaluation

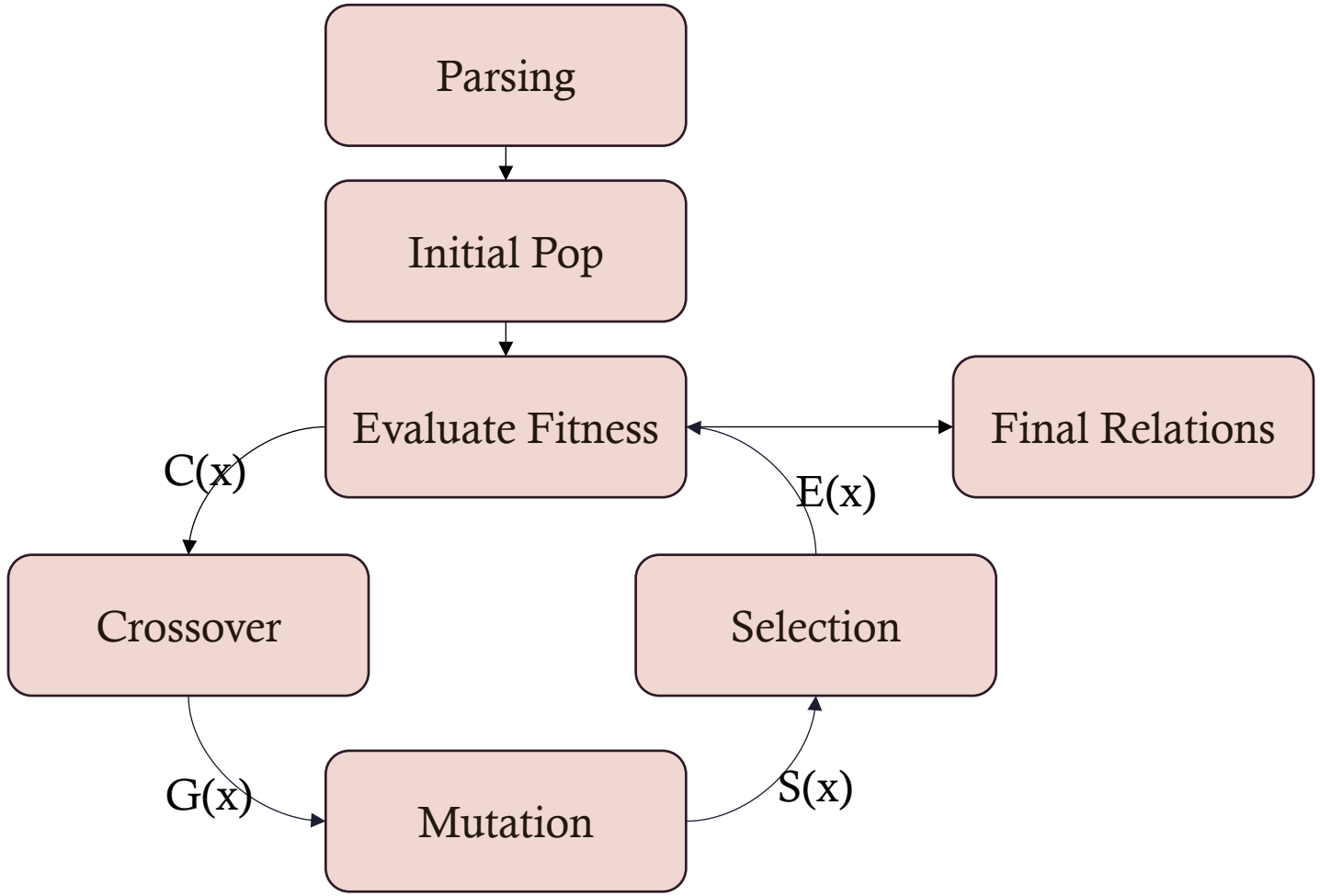
The Initial Population consists of nothing more than naïve groupings so constructed using Automated means or with a HW Designer's prerogative.

While the Fitness Evaluation calculates time-lagged cross-correlations and mutual information between signals to gauge their relationships.

Genetic Operators - Crossover & Mutation

Crossover: Bringing segments of two parent solutions into one to produce offspring, blending features from each to explore new solution spaces.

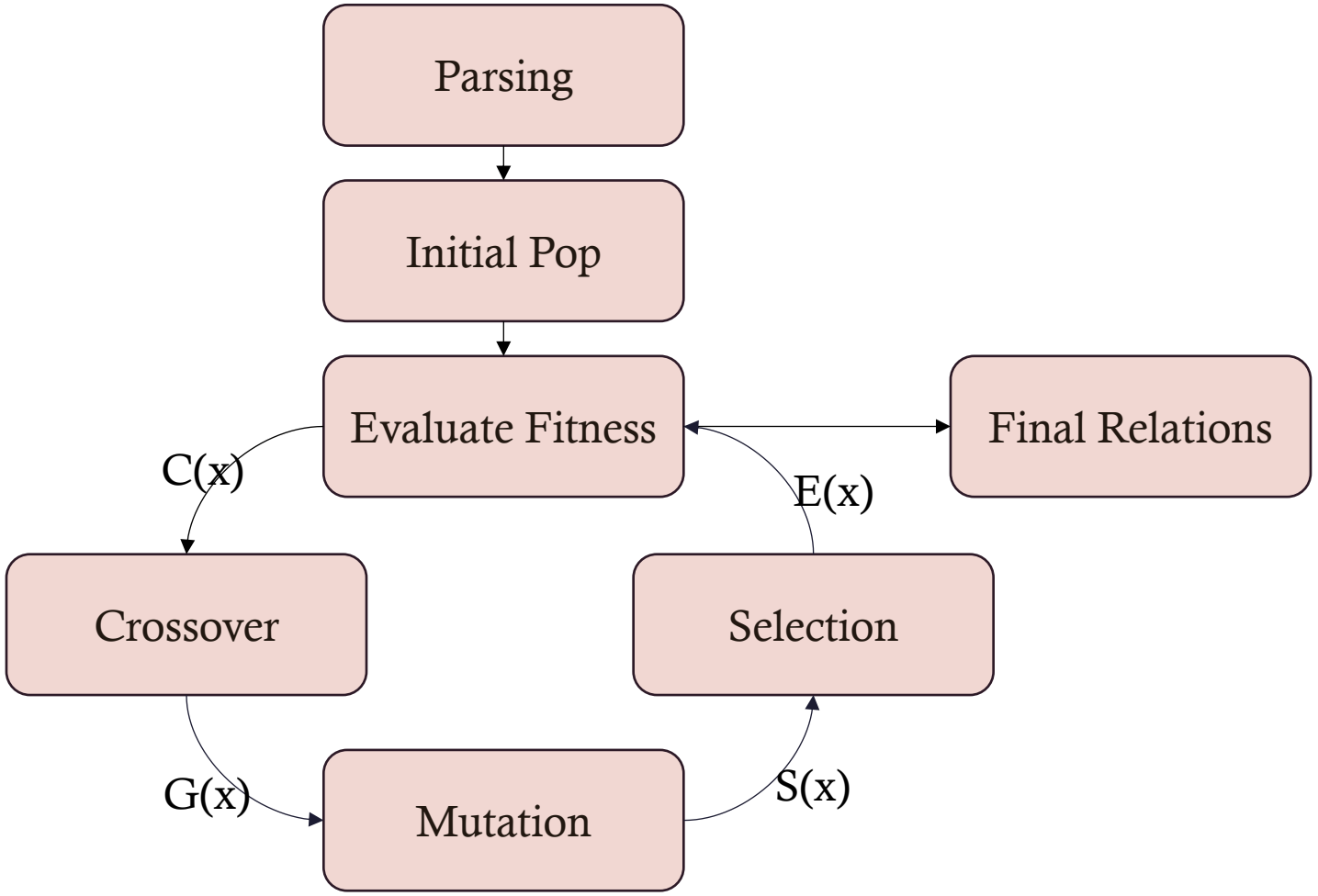
Mutation: Introducing small random changes to an individual solution, helping maintain genetic diversity and allowing the algorithm to escape local optima.



Iteration & Optimization

Only the most viable solutions are allowed to propagate. Continuing their *reproduction* so to mutate into better combinations and solutions over time.

Each iteration through mutation and competition homing in on the most optimal solutions for causality



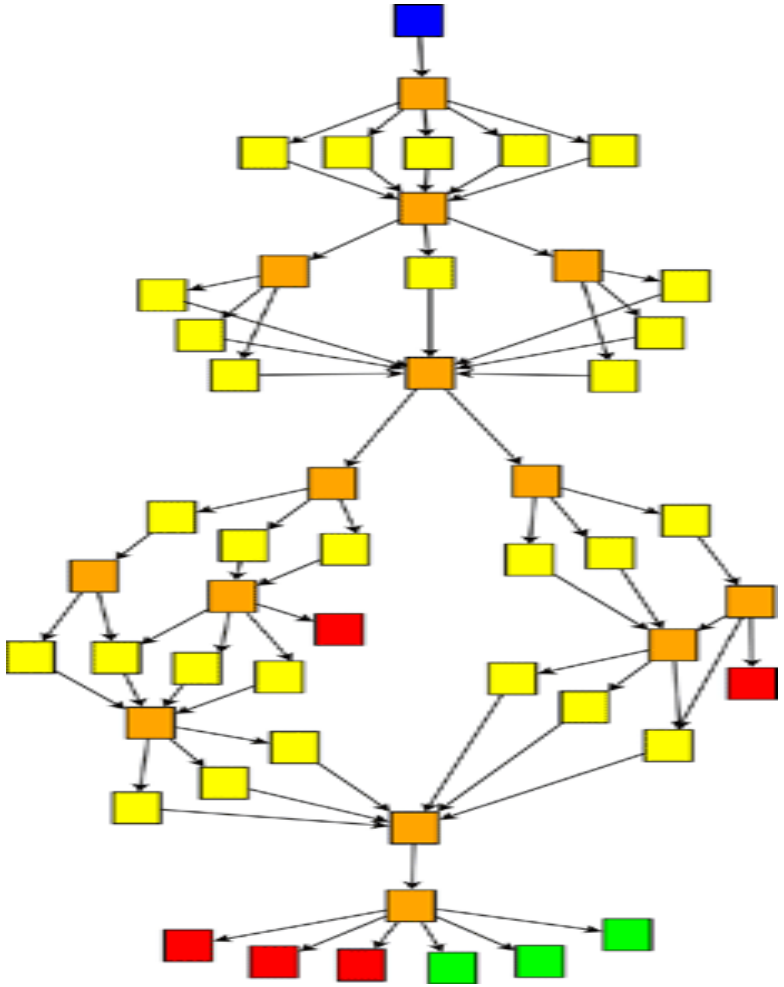
VERIFICATION & ANOMALY DETECTION

THE ADVANTAGES OF GA

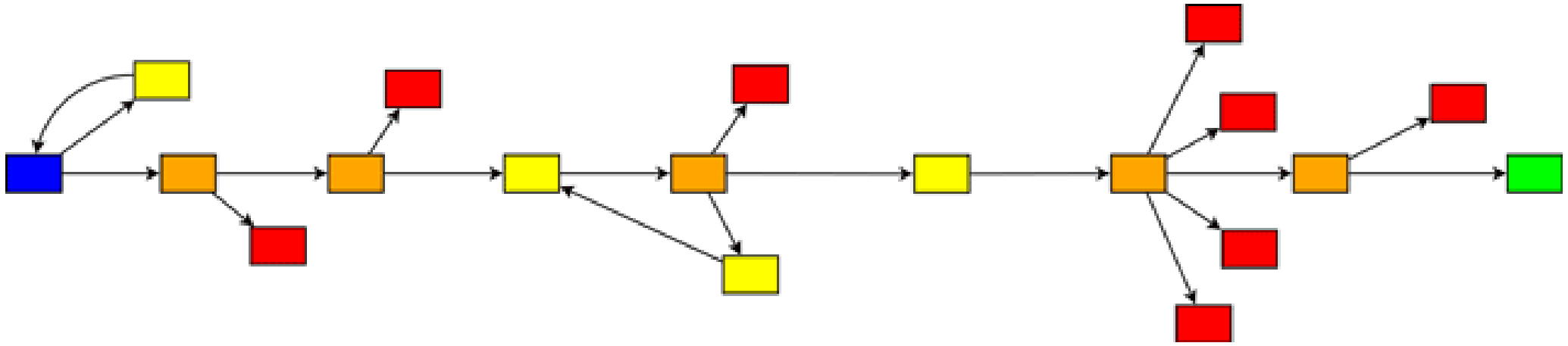
- Having constructed the Causal relationships we can thus approach verification through programmatic methods.

- These relationships can further be used to construct knowledge graphs that easily reduce the vast problem of manual search, often taking exponential amount of time to naive graph search problems.

- These causal graphs ease the verification of designs from Specification files by enabling the user to compare these generated graphs to actual design so produced.



THE WAY FORWARD

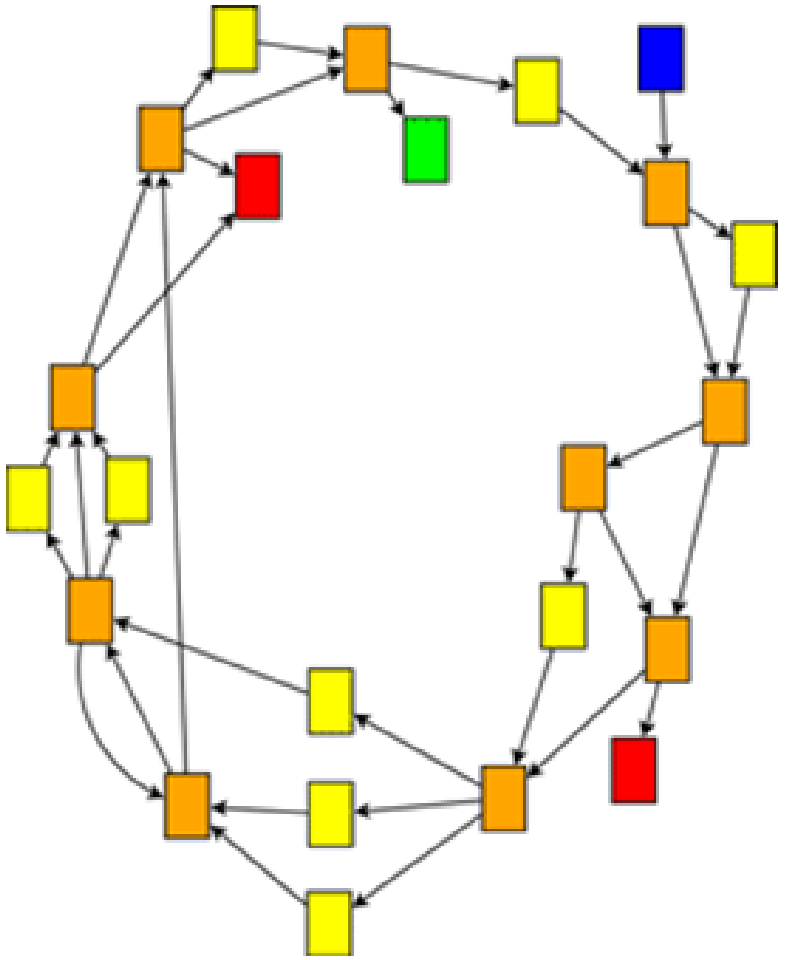


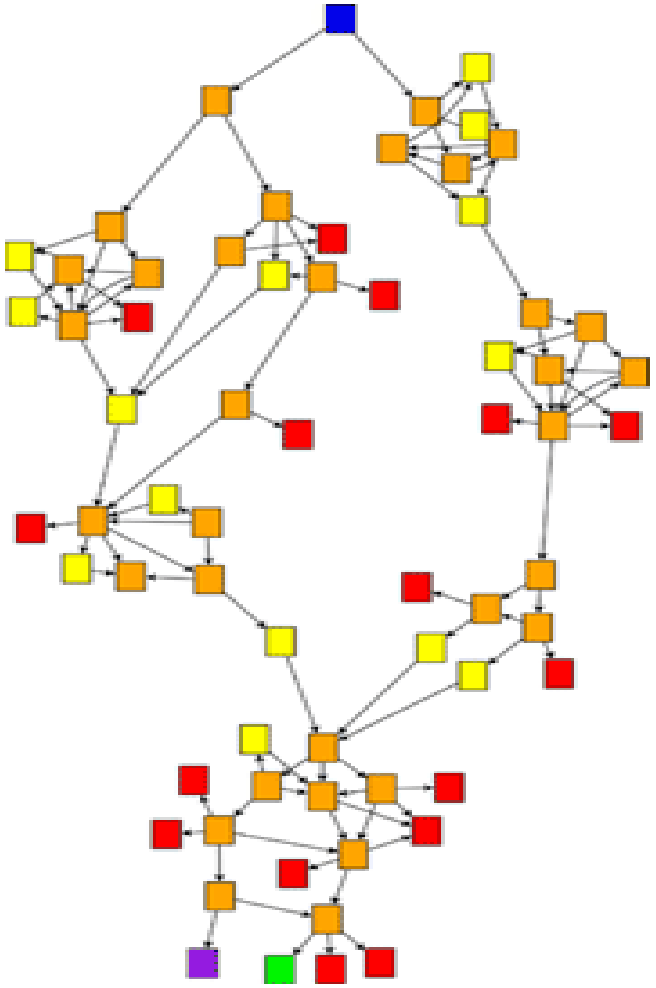
ANOMALY DETECTION

By mapping out signal relationships, the approach can identify signals behaving outside expected patterns, potentially flagging design issues early.

Detecting anomalies in interactions allows engineers to catch and resolve issues that could lead to functional errors, improving overall design reliability.

These causal relationships allow for an easy, human friendly format for simplified verification of logical intricacies in the specification and the actual simulation results.





GA-BASED CAUSAL ANALYSIS

Used Genetic Algorithms to uncover causal relationships between signals from VCD data alone, without needing additional design dependence.

This method automatically evolves and refines groups of signals that influence each other, identifying meaningful dependencies directly from the data.

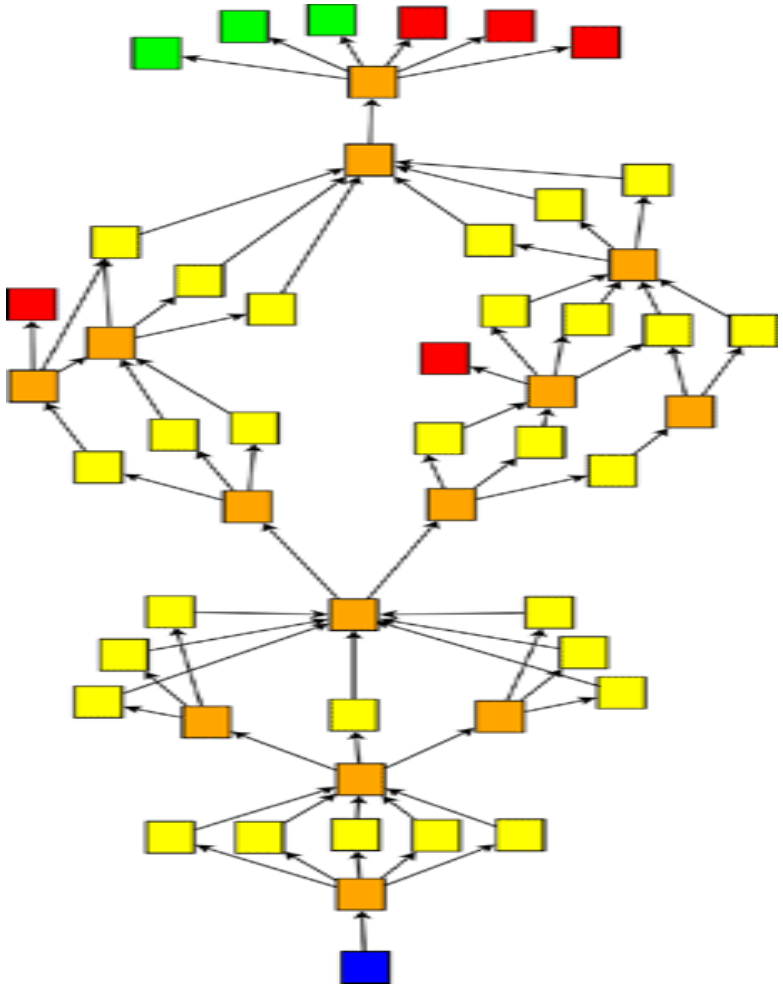
By focusing on data-driven relationships, this approach reduces the need for manual, time-intensive analysis.

AUTOMATION IN VERIFICATION

GA-driven analysis automates the process of identifying interactions between signals, streamlining verification workflows.

This automation means verification engineers can focus on evaluating these relationships instead of manually discovering them, accelerating the verification timeline.

It enables scalable, consistent verification even for complex designs with numerous interacting signals.



THANK YOU

- Hardik Raina
- ML Engineer
- Agnisys
- hardik@agnisys.com