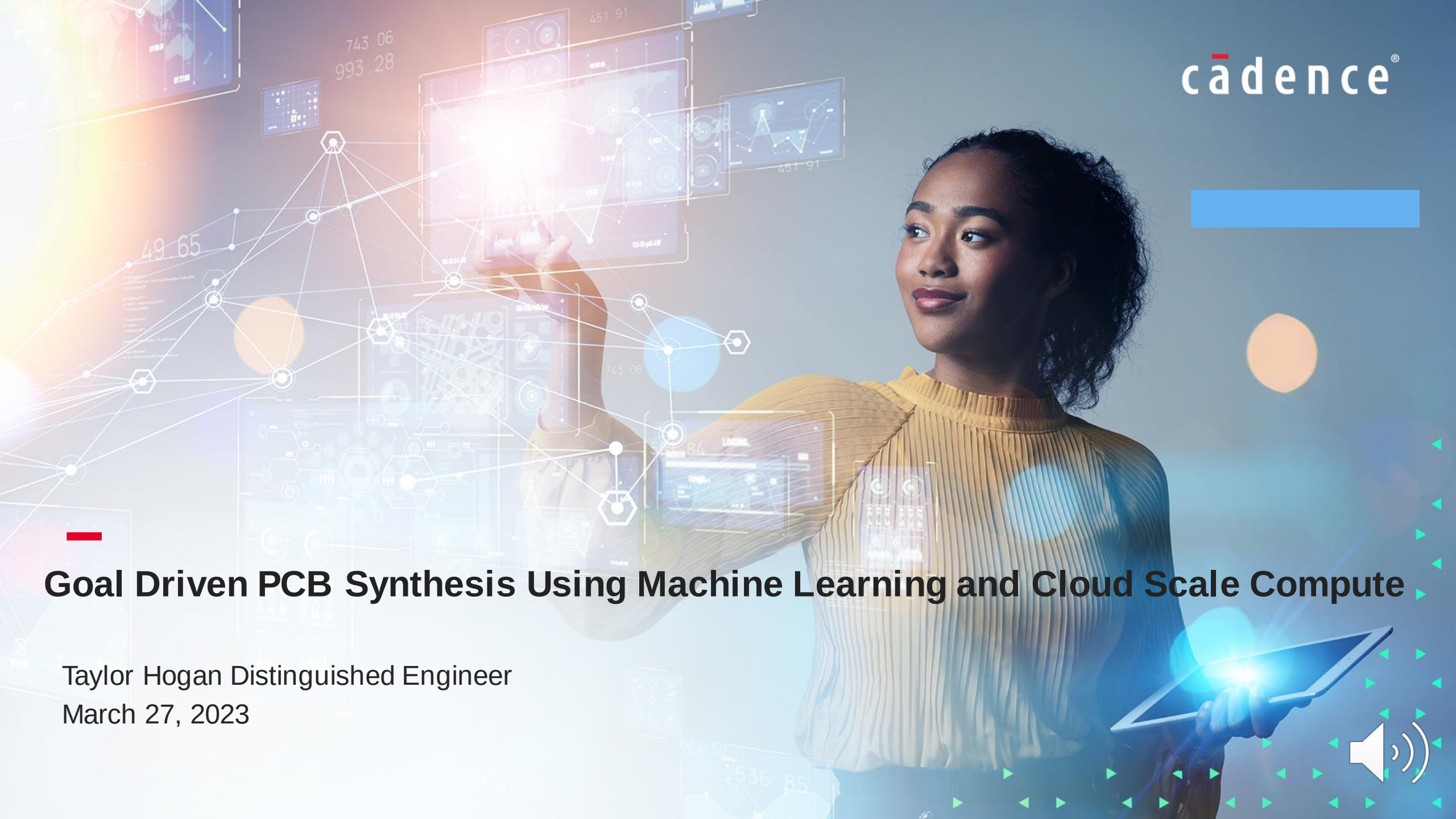


Goal Driven PCB Synthesis Using Machine Learning and Cloud Scale Compute

Taylor Hogan Distinguished Engineer

March 27, 2023

Themes

- PCB Design is a Manual Process
  - The solution space is large
- Large Training Sets Available
  - Can be autonomously created
- Designs Mostly Share Common DNA
  - Same parts, Same Manufacturing Facilities
- Competitive Disadvantage if Not using ML
  - It works, let me prove it
- Cloud Scale Compute

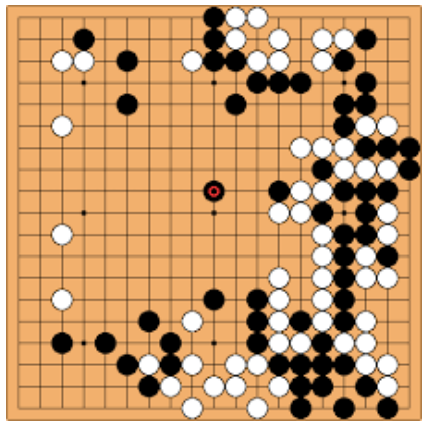
Design Spaces are Huge

- Complexity of search space is much larger than those of recent successes
  - No hope of using pure trial and error or machine learning
- Need algorithms that automatically learn heuristics to prune search space based off a set of designs or styles

Chess

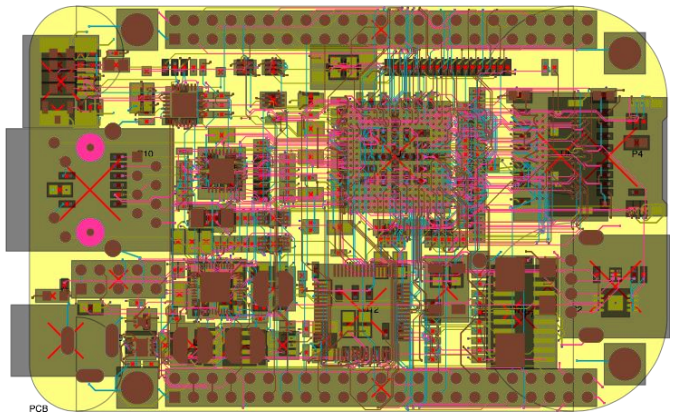
10^{47}

Go



10^{170}

PCB Placement

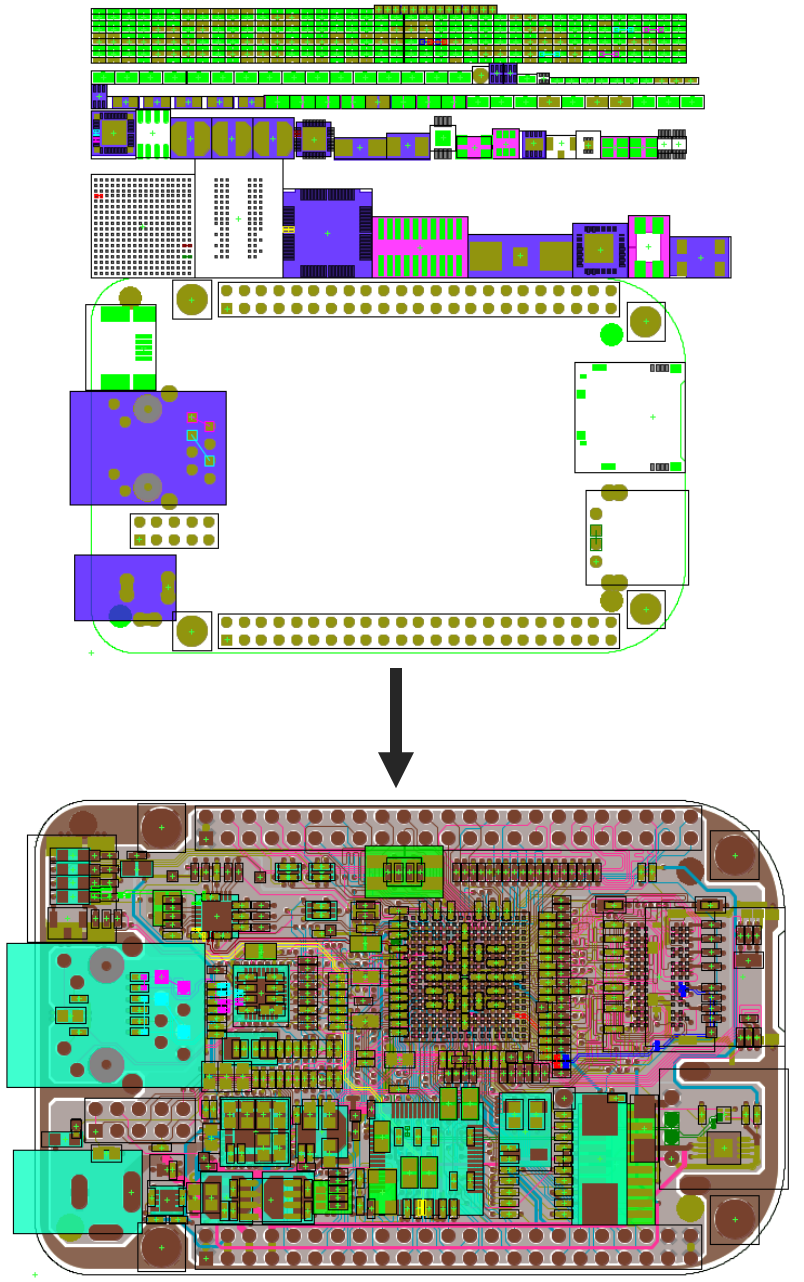


10^{262}

* https://en.wikipedia.org/wiki/Game_complexity

Design is Difficult

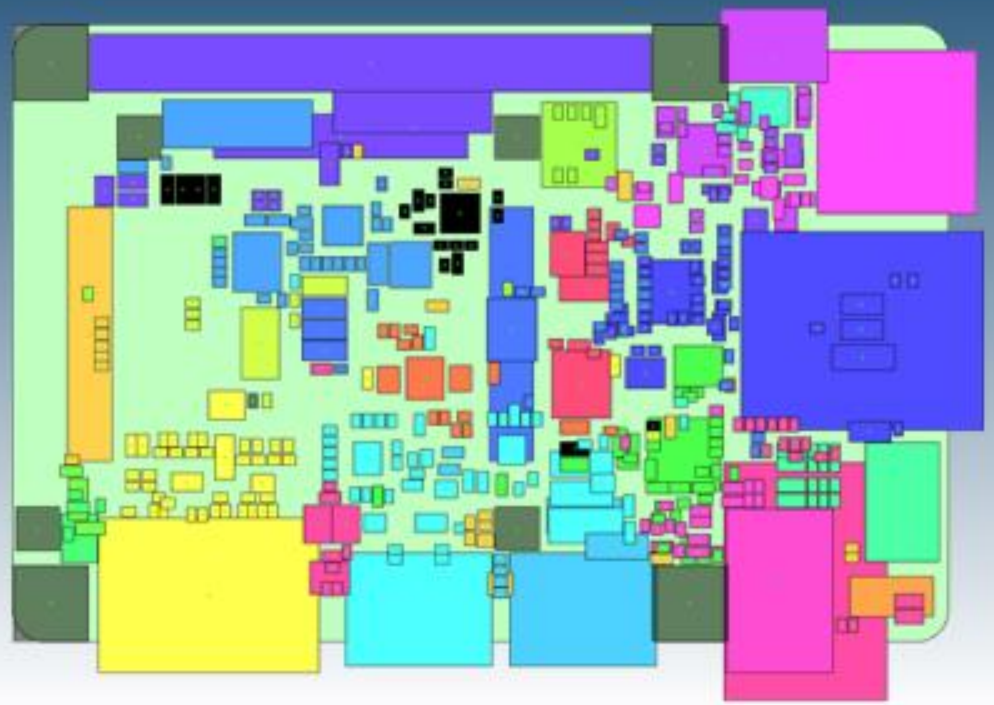
- Computationally Intractable
  - Placement is either ill-posed or NP-Hard
  - Routing is NP-hard (even determining if there is a solution is difficult)
- Tradeoff between speed and quality of solutions
  - Exact solutions take time or are rigid
  - Approximate solutions only generalize within distribution
  - Have to design algorithms that are not general purpose, but flexible



X AI

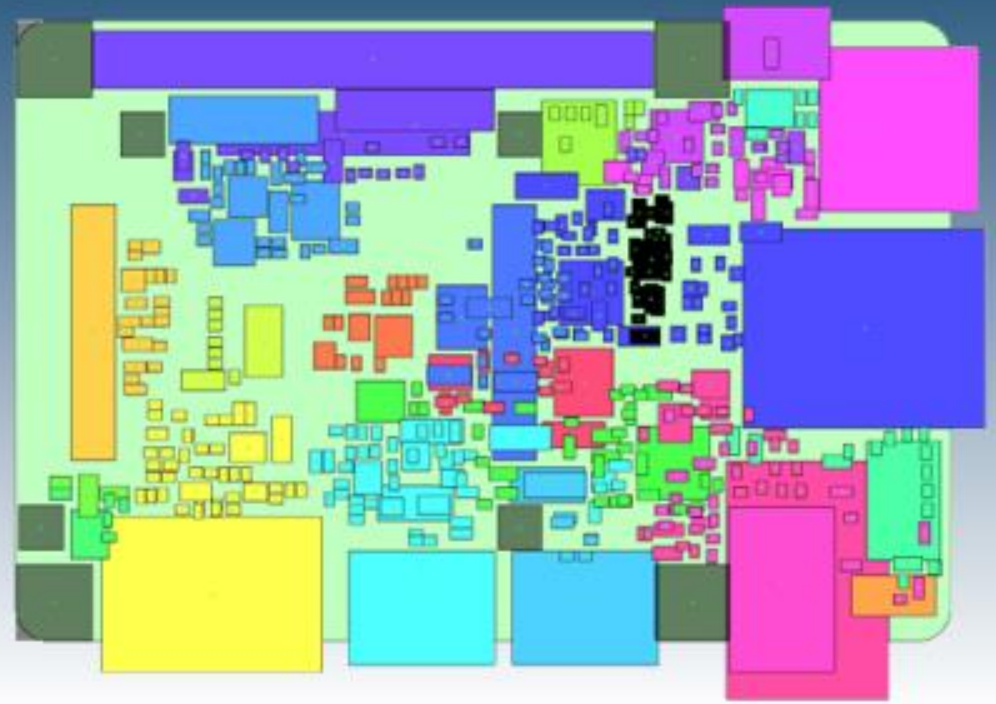
Artificial Intelligence to Reduce Time to Design PCBs – Google Coral Board

Human Placement



~ 3 days Placement

Allegro X: AI Clustering



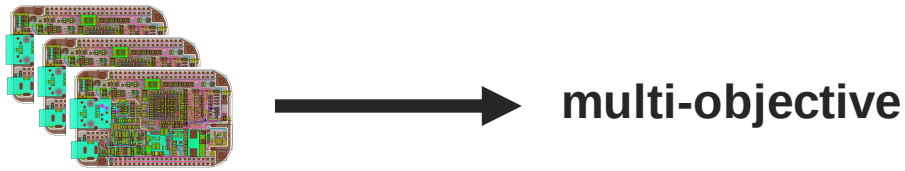
75 minutes
14% better wirelength
Incremental setup time 15 mins

What problems can machine learning solve?

- *ML for prediction problems*

- *ML for design problems*

- *ML at scale*



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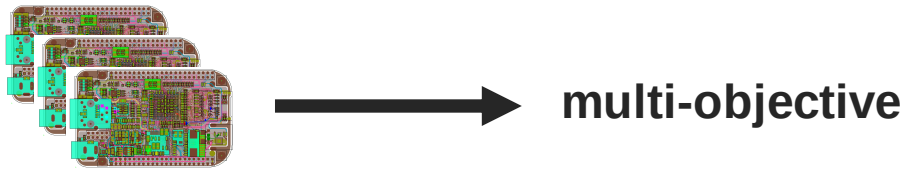
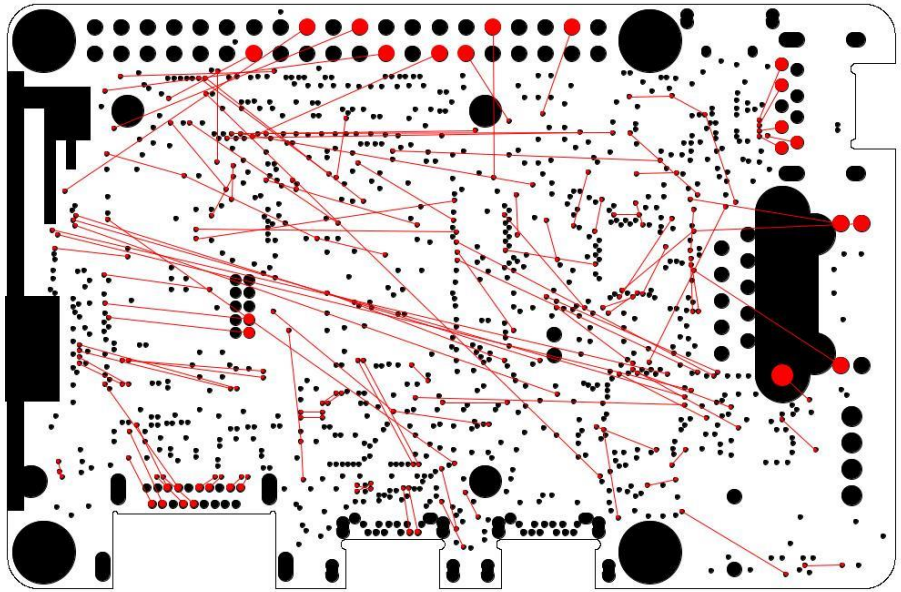


Route Prediction Problems

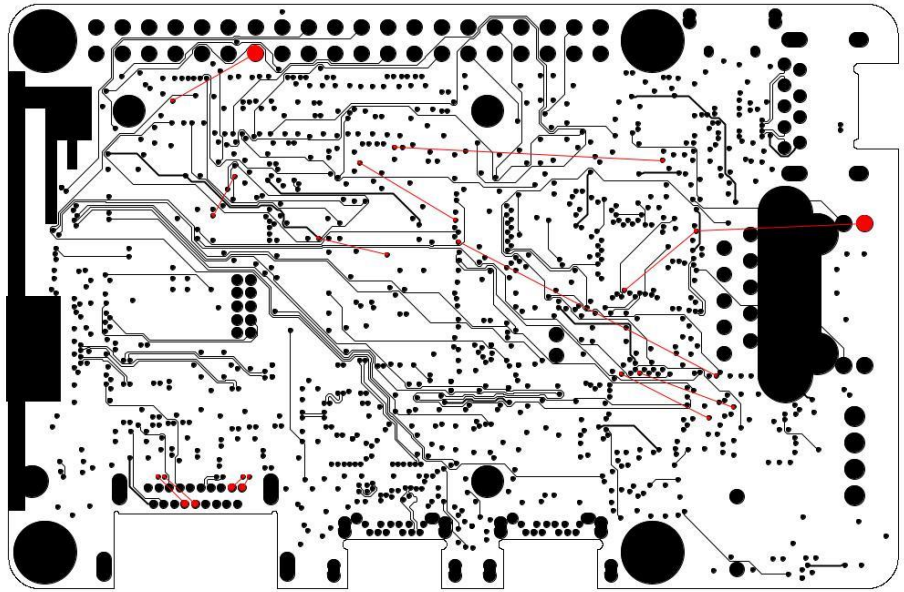
Can we predict the disconnects before we route?

Connections



Router

Routes

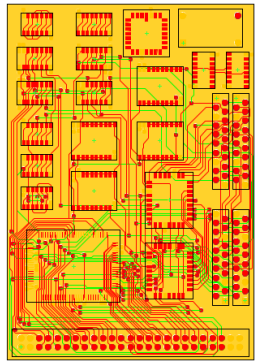


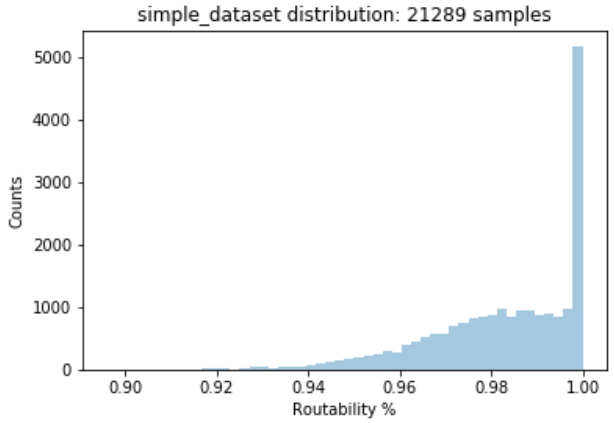
Route Prediction Problems

Building a Dataset

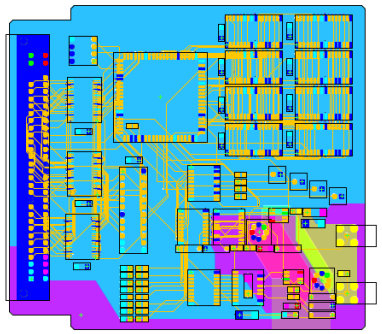
	Board 1	Board 2	Board 3	Board 4	Board 5	Board 6
Training Set Size	12,136	12,362	12,320	20,878	12,761	
Test Set Size	2,962	4,038	4,168	3,102	3,260	1,663

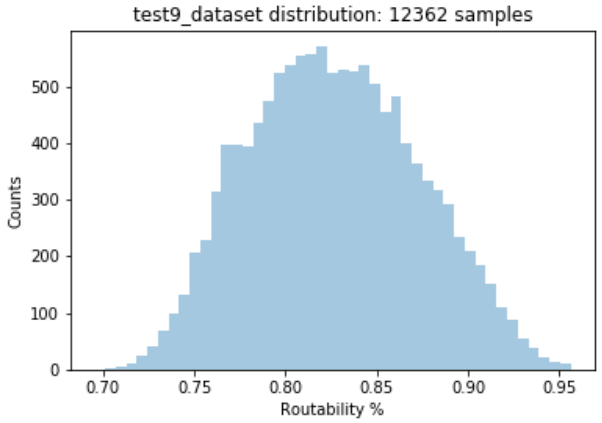
Simple



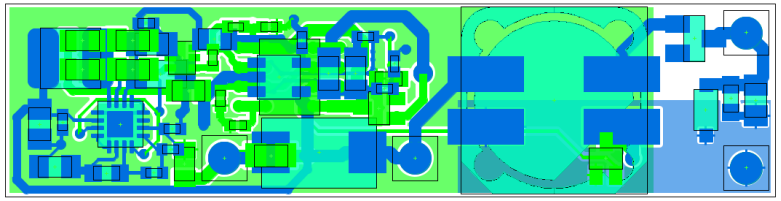


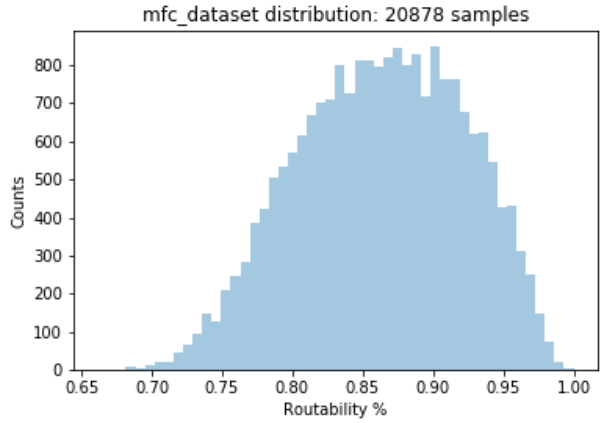
Test9





MFC_TI_Flyback_Rev2





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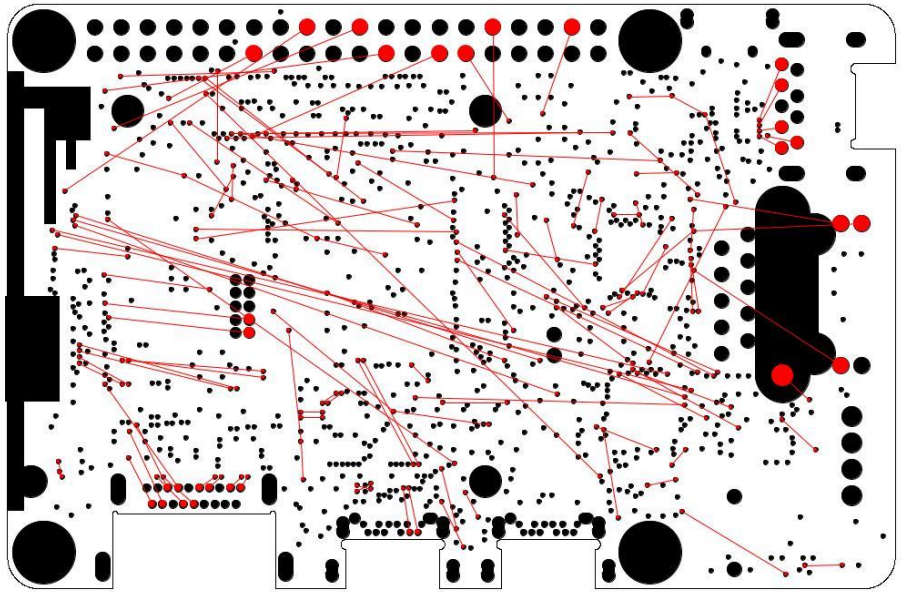
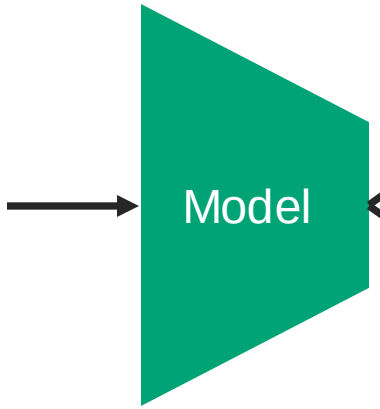
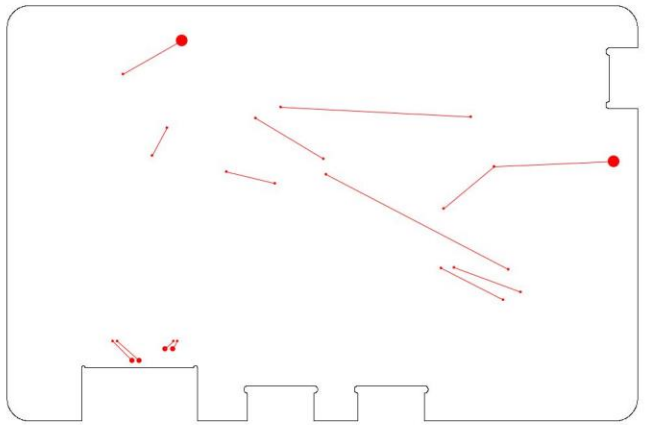




Score: 97% Complete

Scores/Predictions



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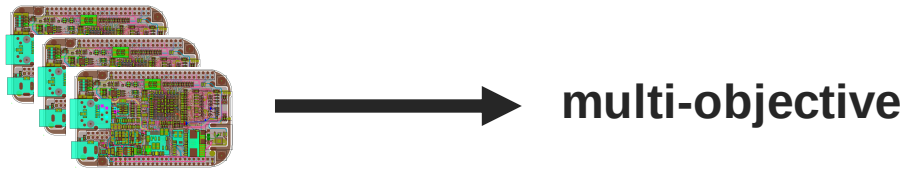
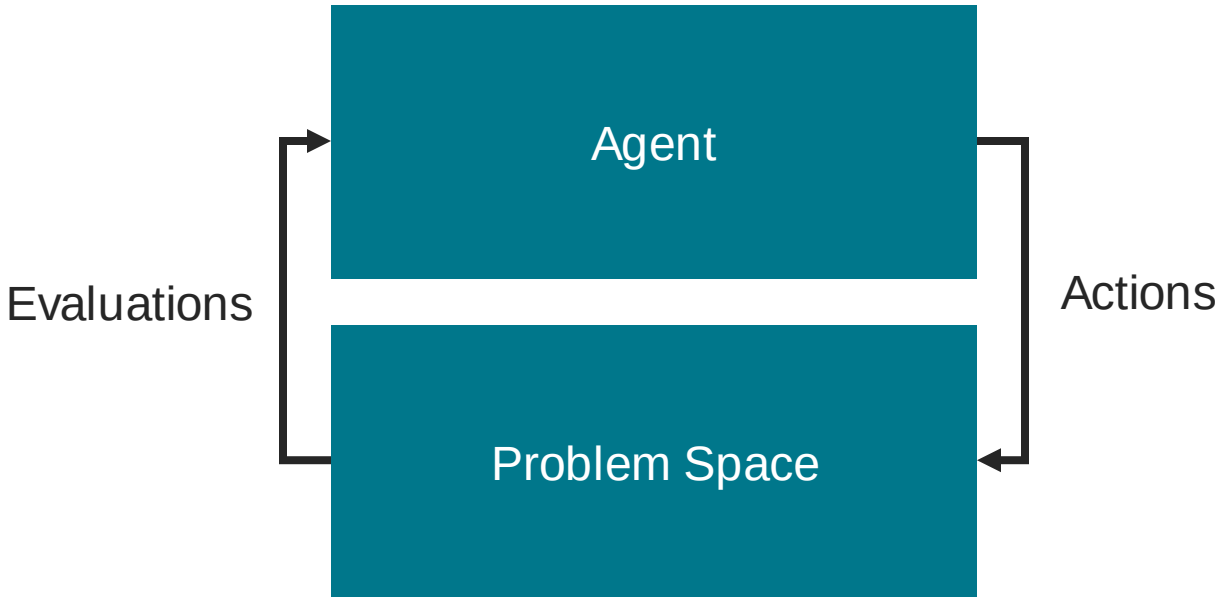


Why Reinforcement Learning?

- General framework for making decisions
- Transfer knowledge from previous problems we have solved in the past
- Learn to solve certain classes of problems efficiently



The Problem

- RL problems are typically cast as a ***Markov Decision Process***

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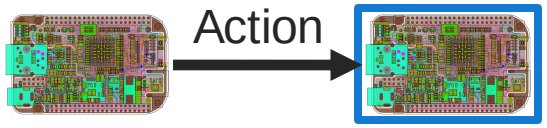
Markov : The current state is all the knowledge I need to make predictions about the next state.



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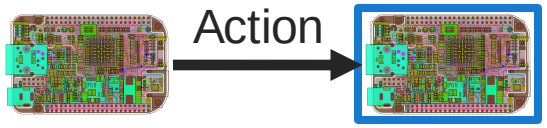
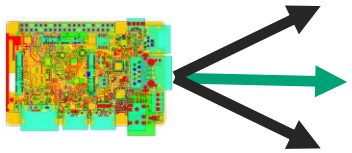
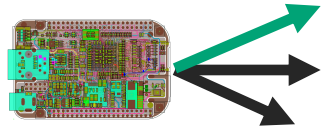


Decision : Which action should I take to get towards my goal state?





The Problem

We can take advantage of this structure

- RL problems are typically cast as a ***Markov Decision Process***

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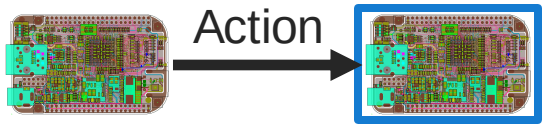
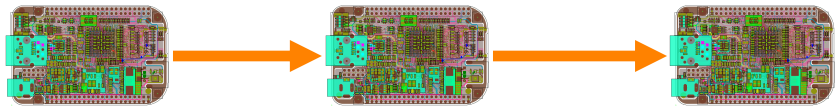


Decision : Which action should I take to get towards my goal state?

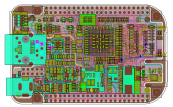
Process : More than one action will be required to reach my goal.



The Solution

Monte Carlo Tree Search

Search



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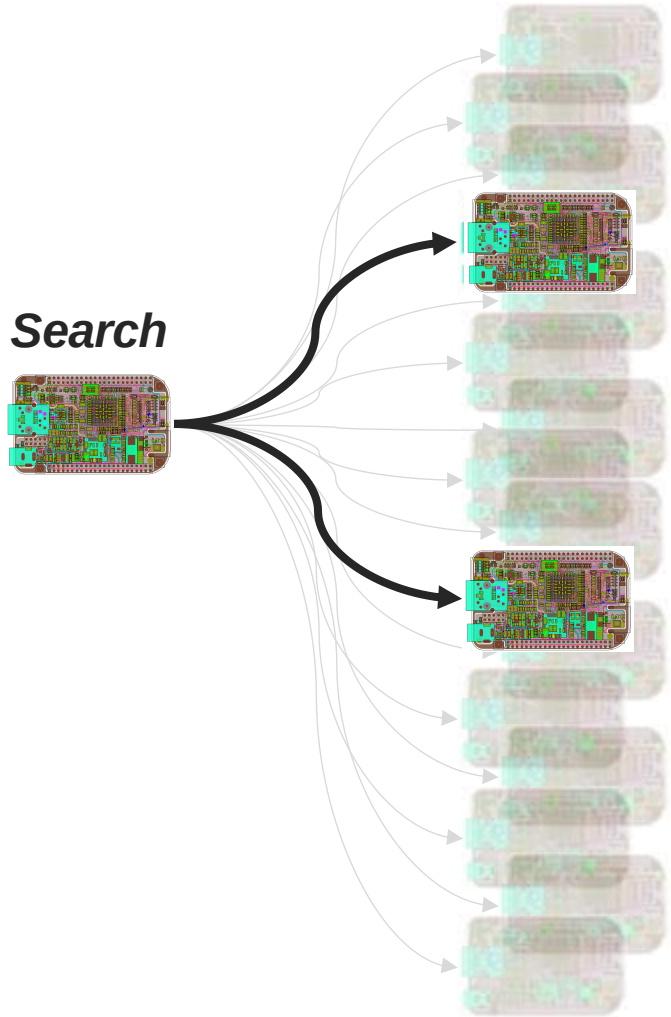

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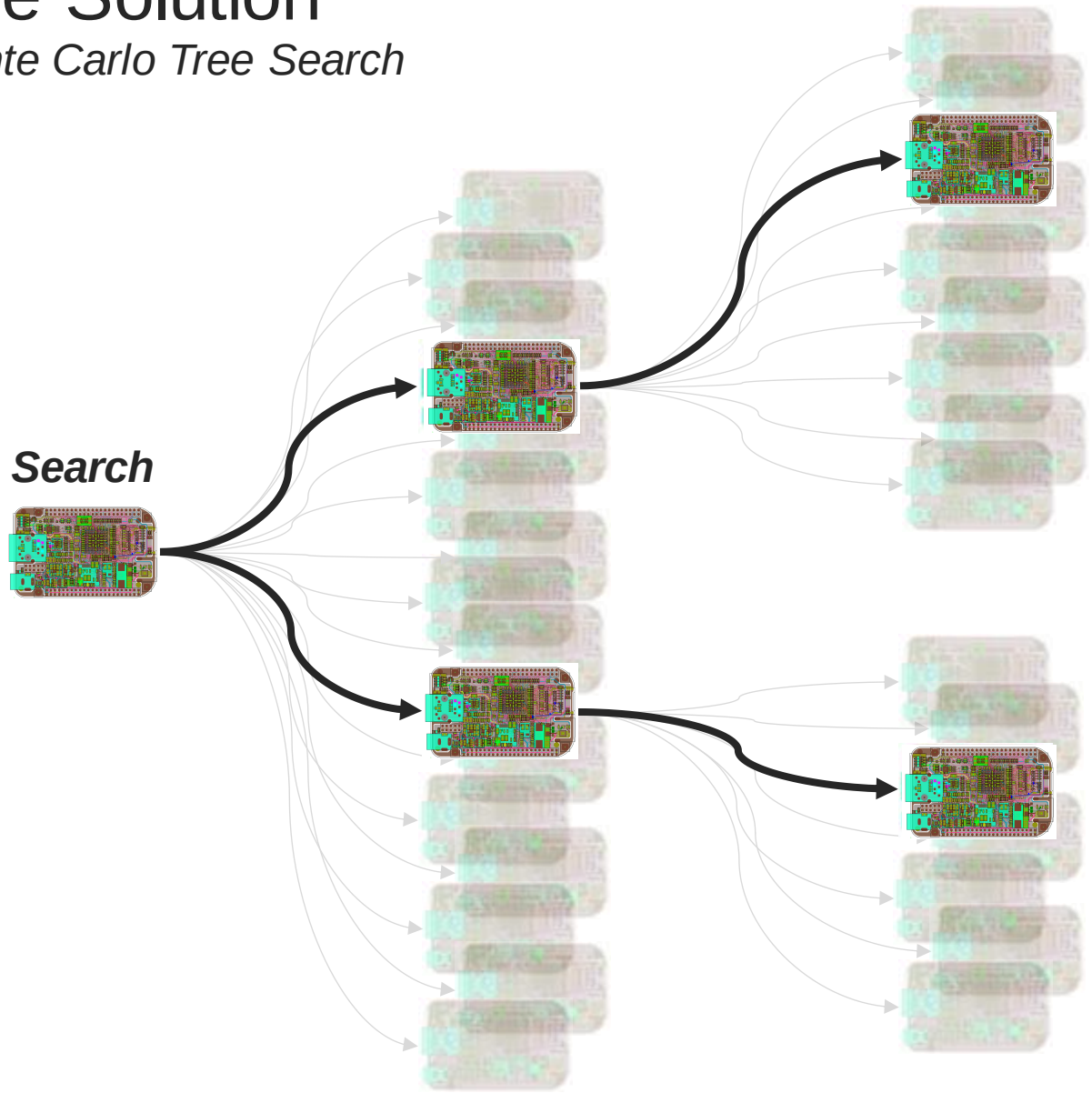

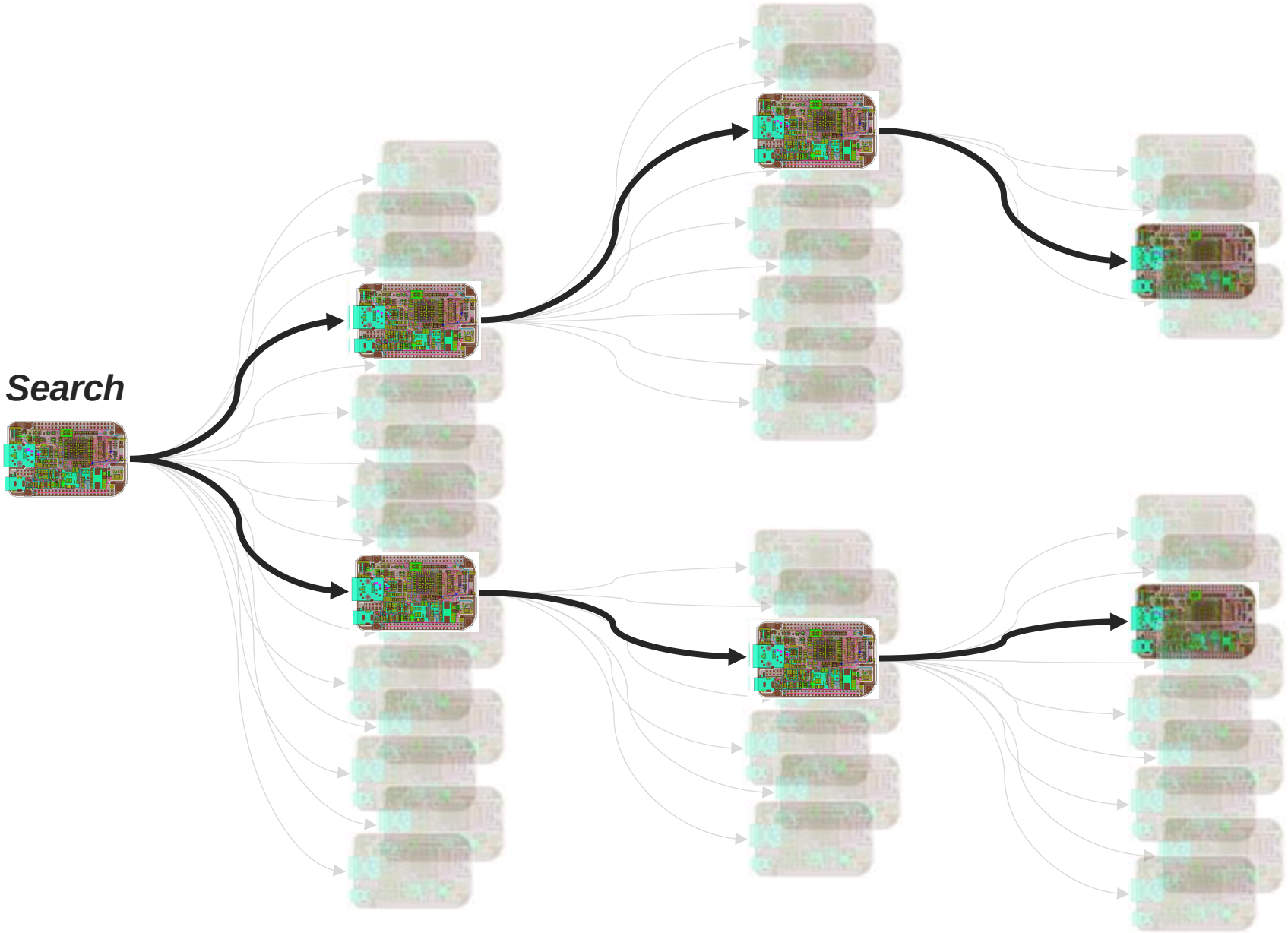

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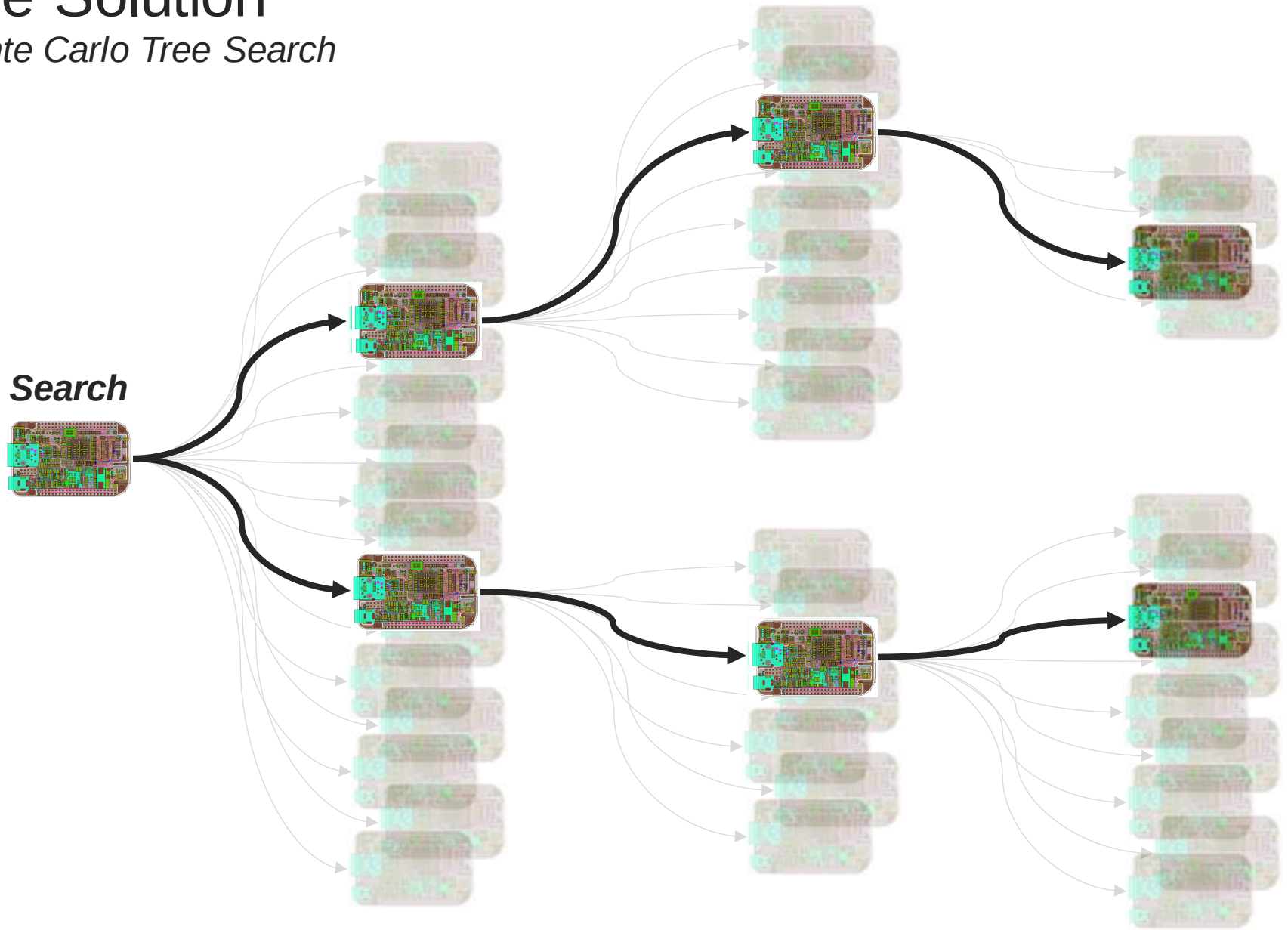
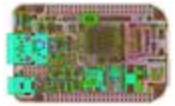
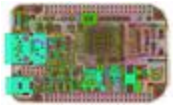




*"… using **physics-based analysis** and **high-level design goals**."*



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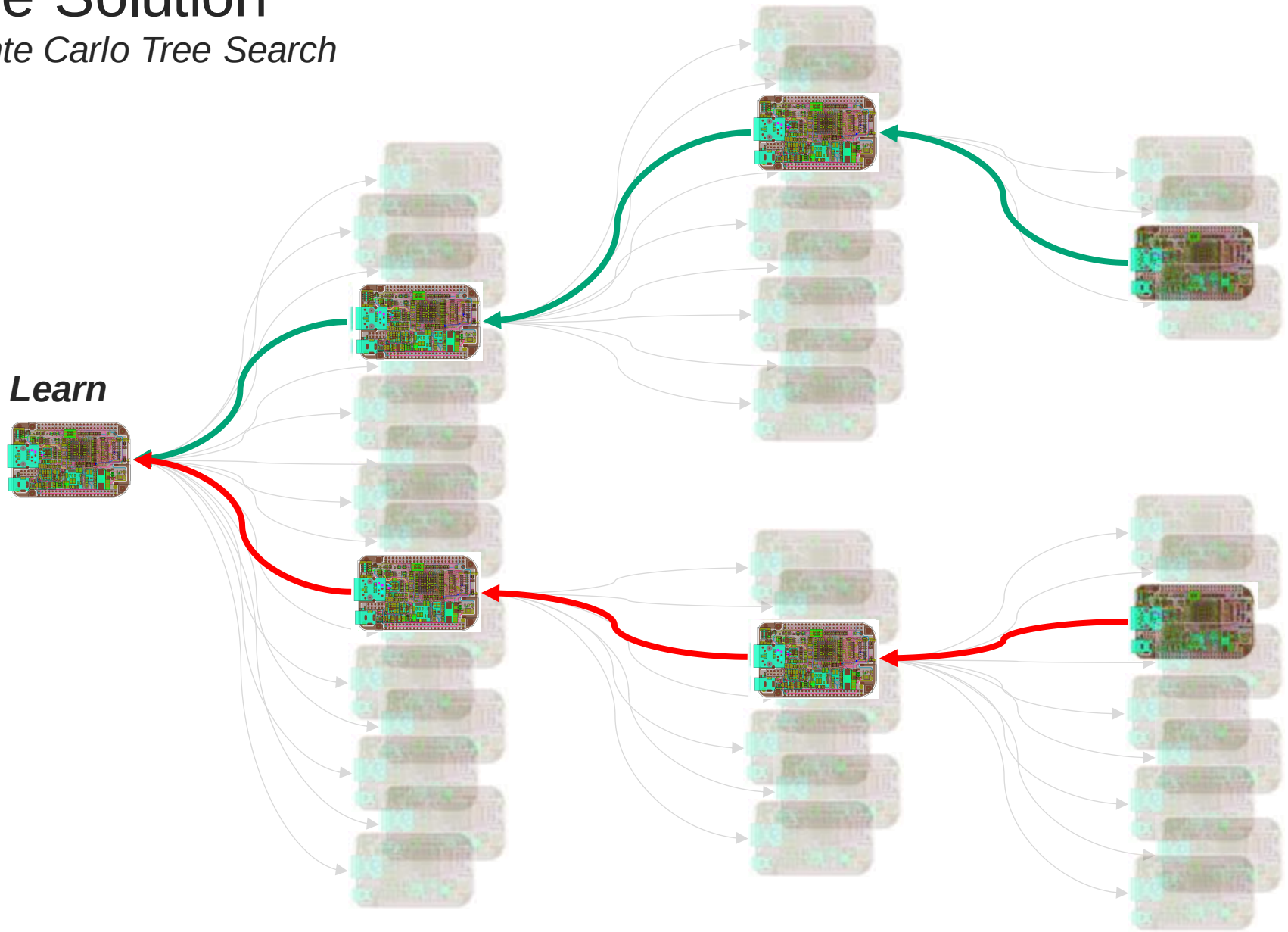

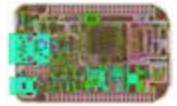

✓

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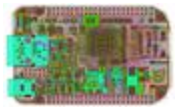
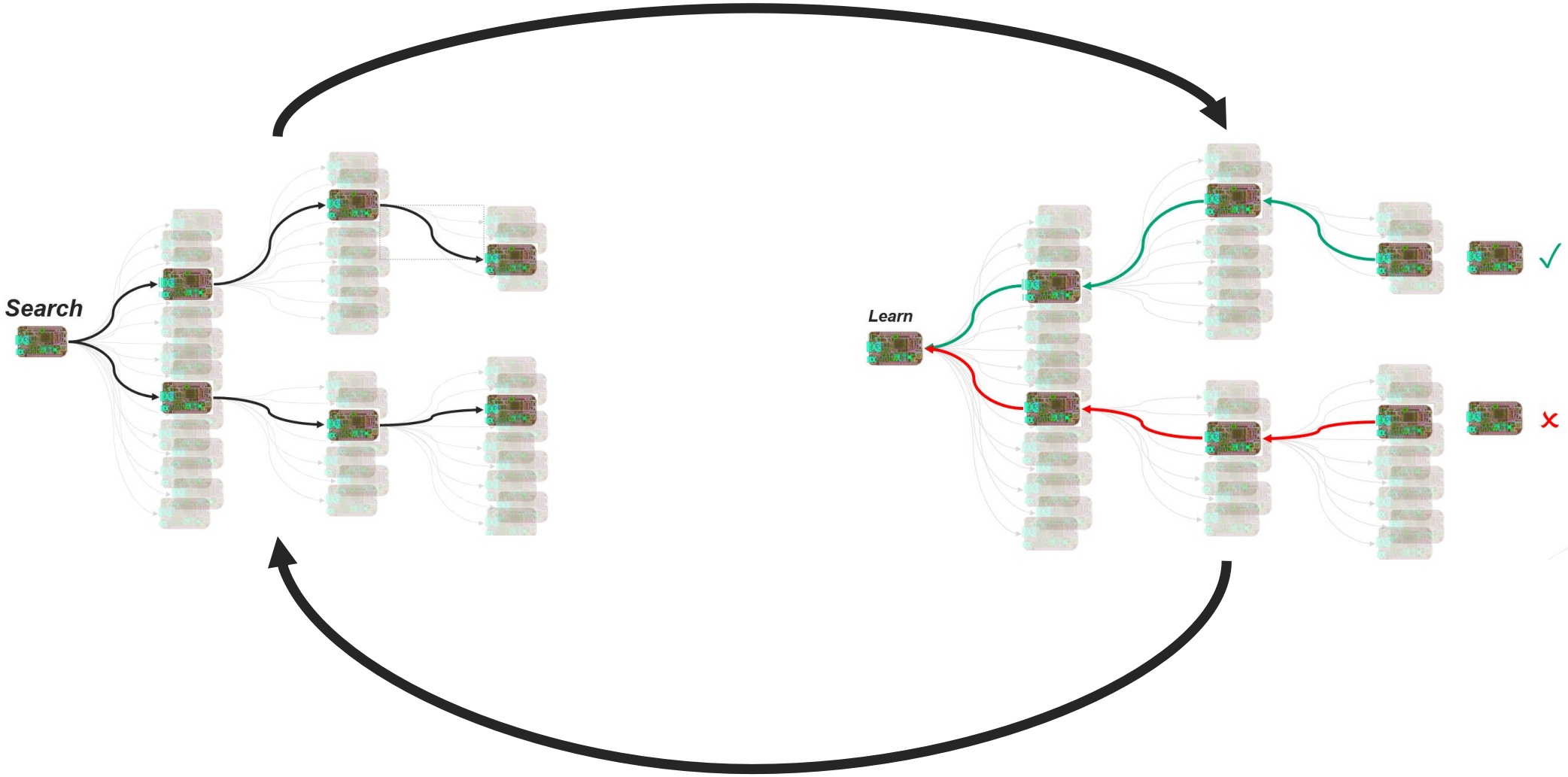


✗

cadence

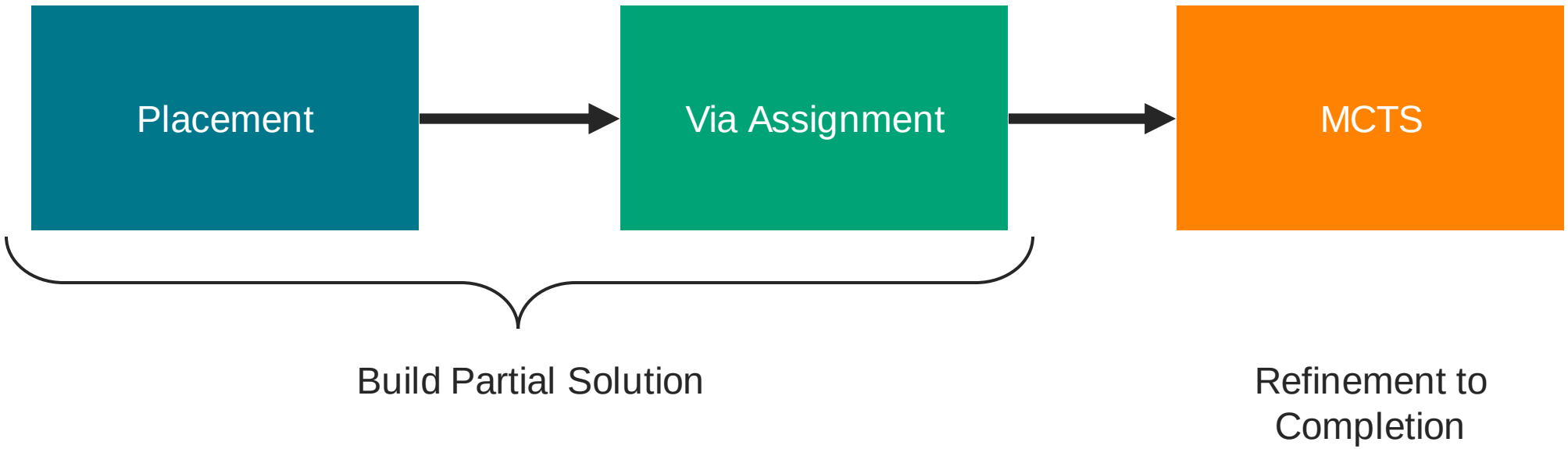
MCTS for PCB Design

Feedback Loop



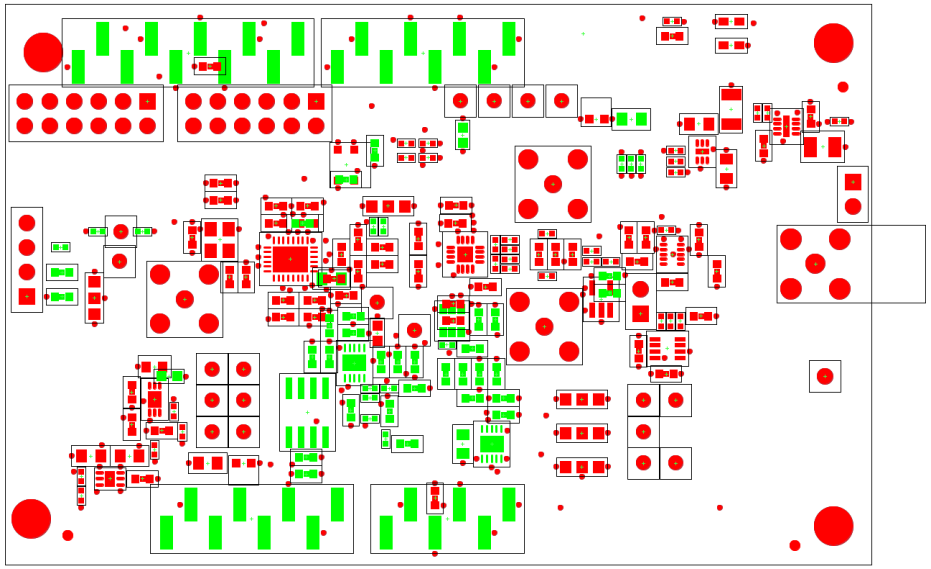
MCTS In Practice

Refinement of Partial Boards

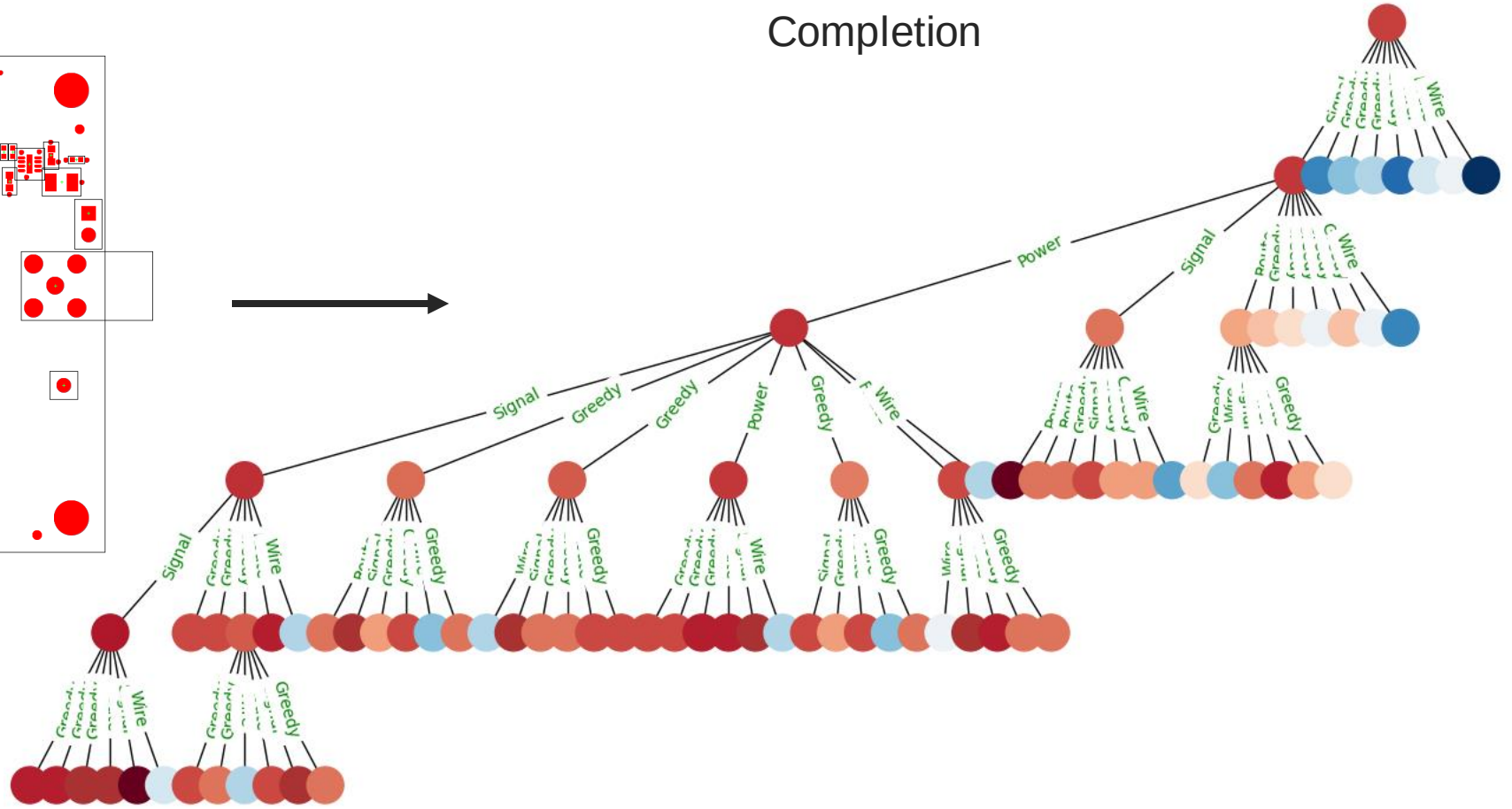


MCTS In Practice

Build Partial Solution



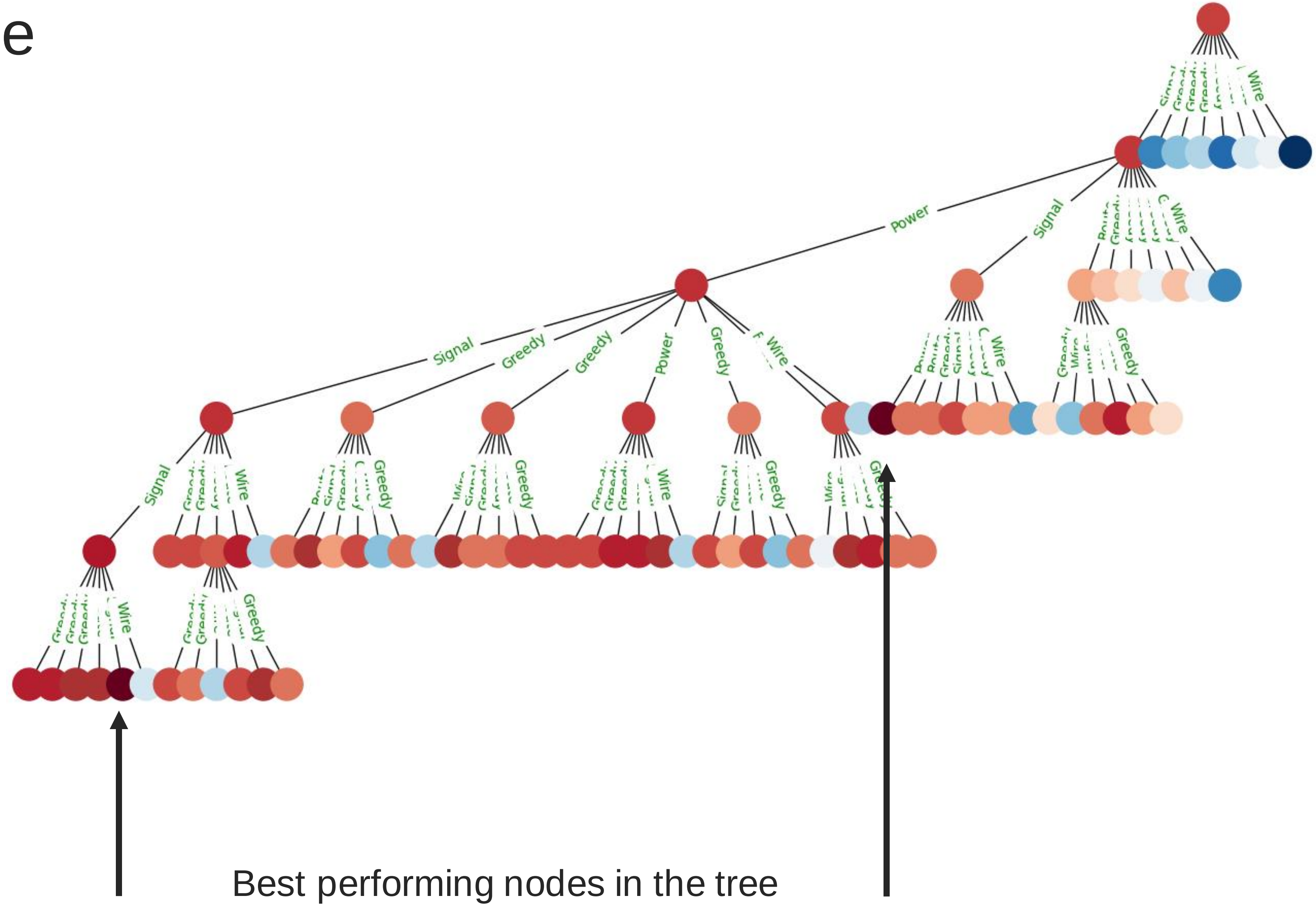
Refinement to Completion



MCTS In Practice

Search Tree

- MCTS adaptively chooses which search directions are worth pursuing
- It might find multiple solutions that are the same value



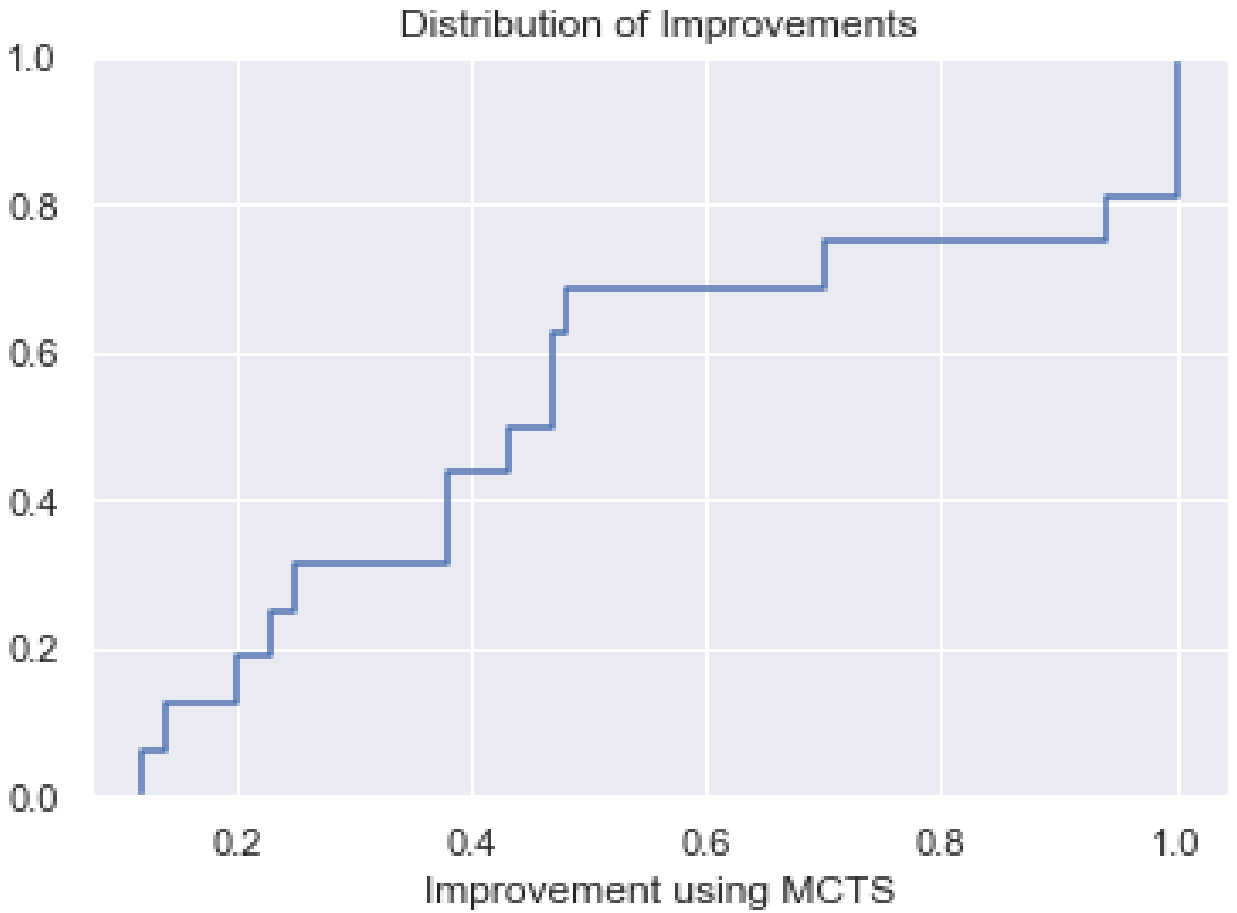
Best performing nodes in the tree

cādence®

MCTS In Practice

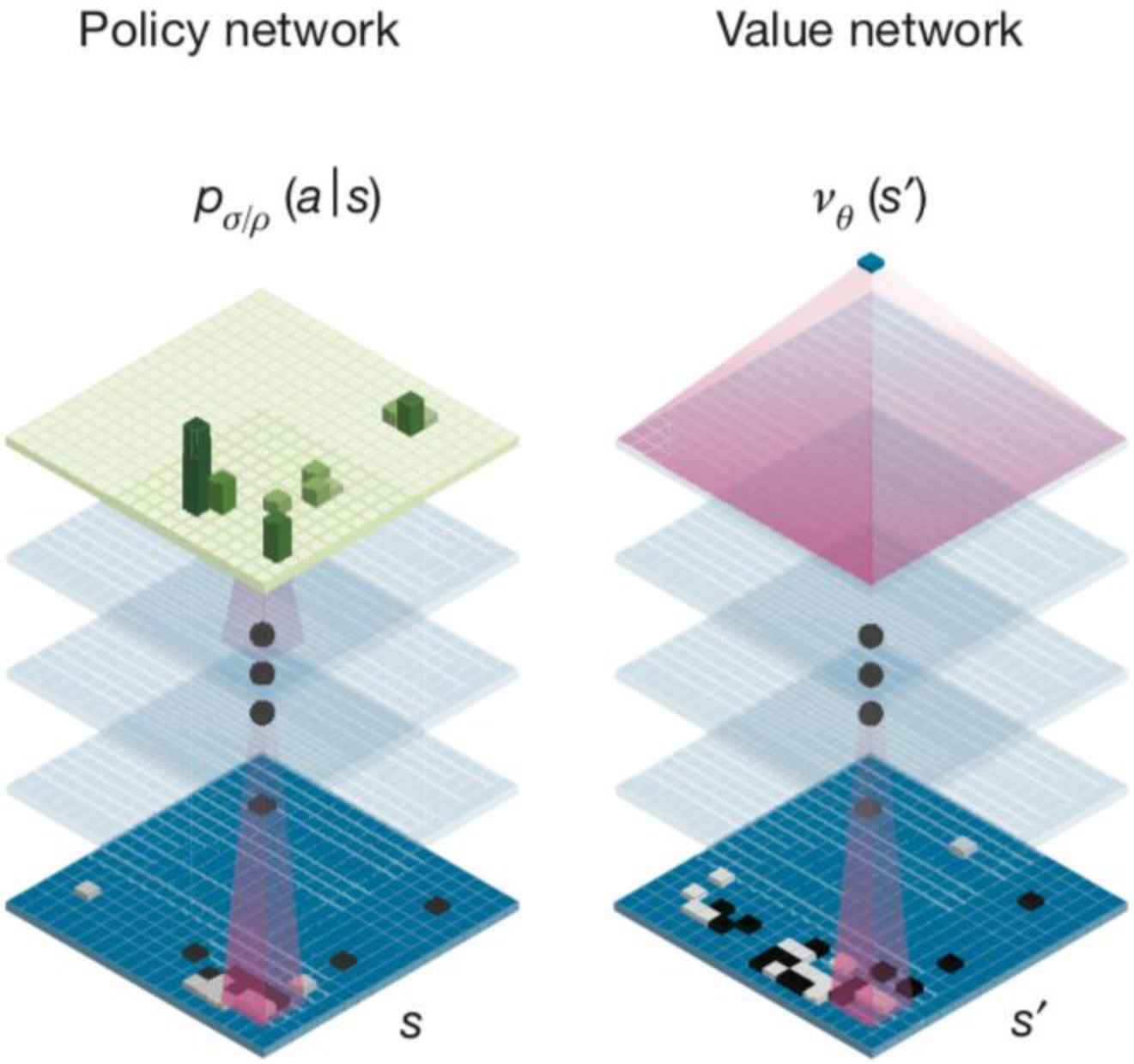
Benchmark Results

- Suite of approximately 30 focus designs
- On average a design gets over 50% improvement over just routing
- Some designs can only reach route completion with MCTS-based feedback
- Next steps are to identify a more expressive actions space to help bring all designs to completion



AlphaGO

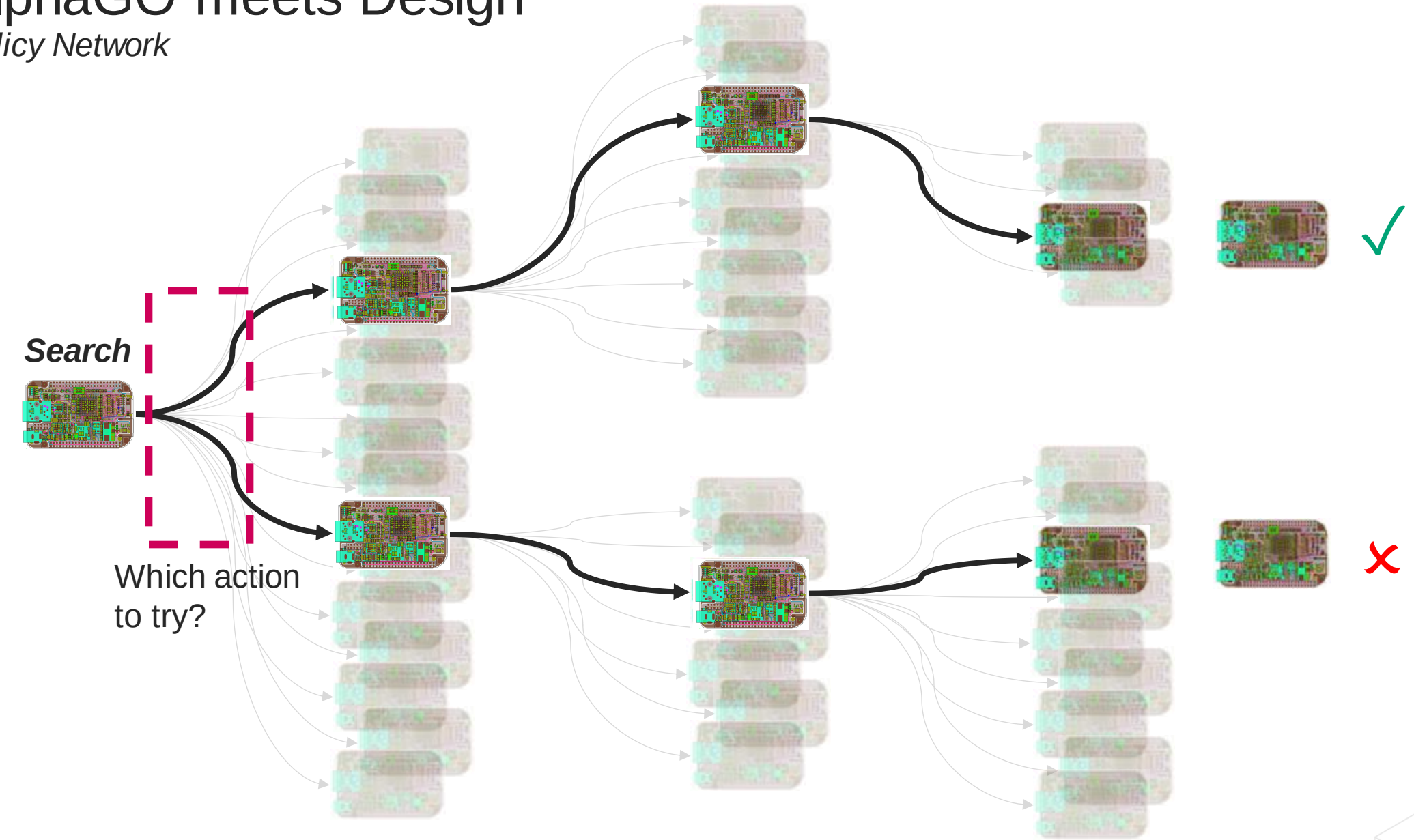
Learning to search



https://www.nature.com/articles/nature24270

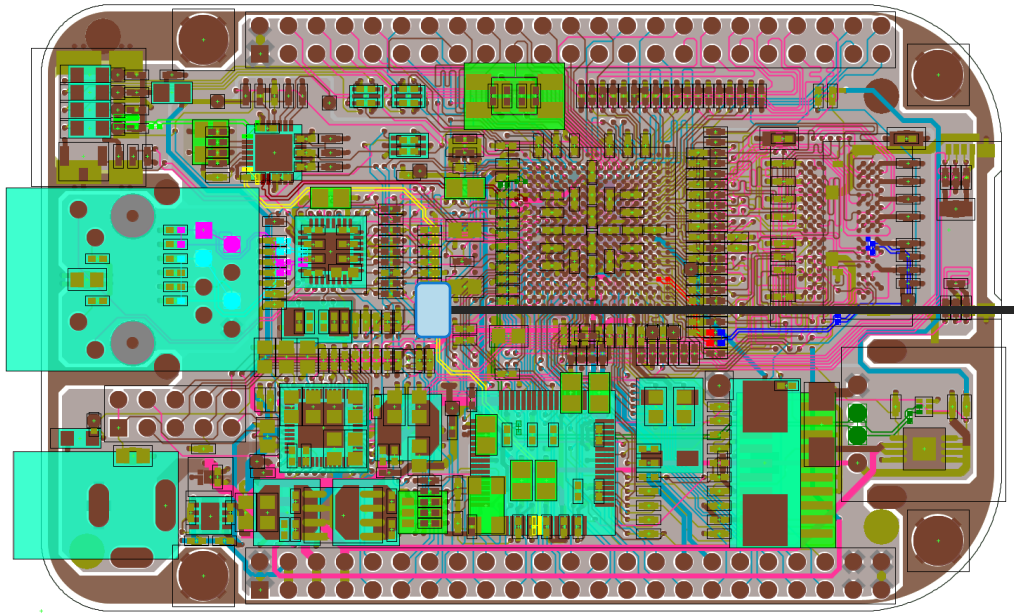
AlphaGO meets Design

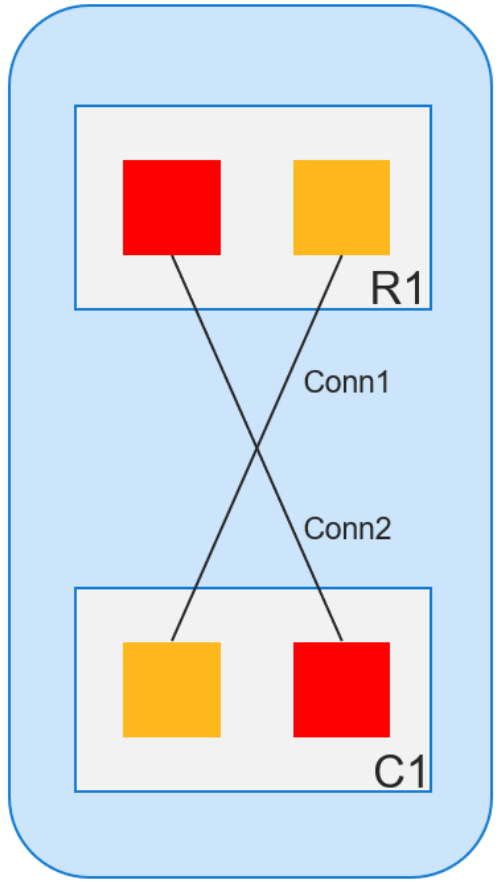
Policy Network



MCTS for PCB Design

Policy Network

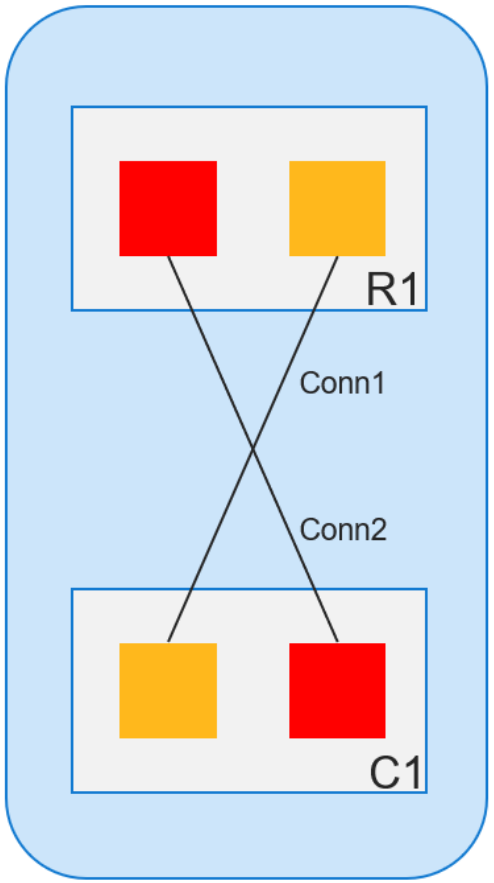




State

MCTS for PCB Design

Policy Network



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MCTS for PCB Design

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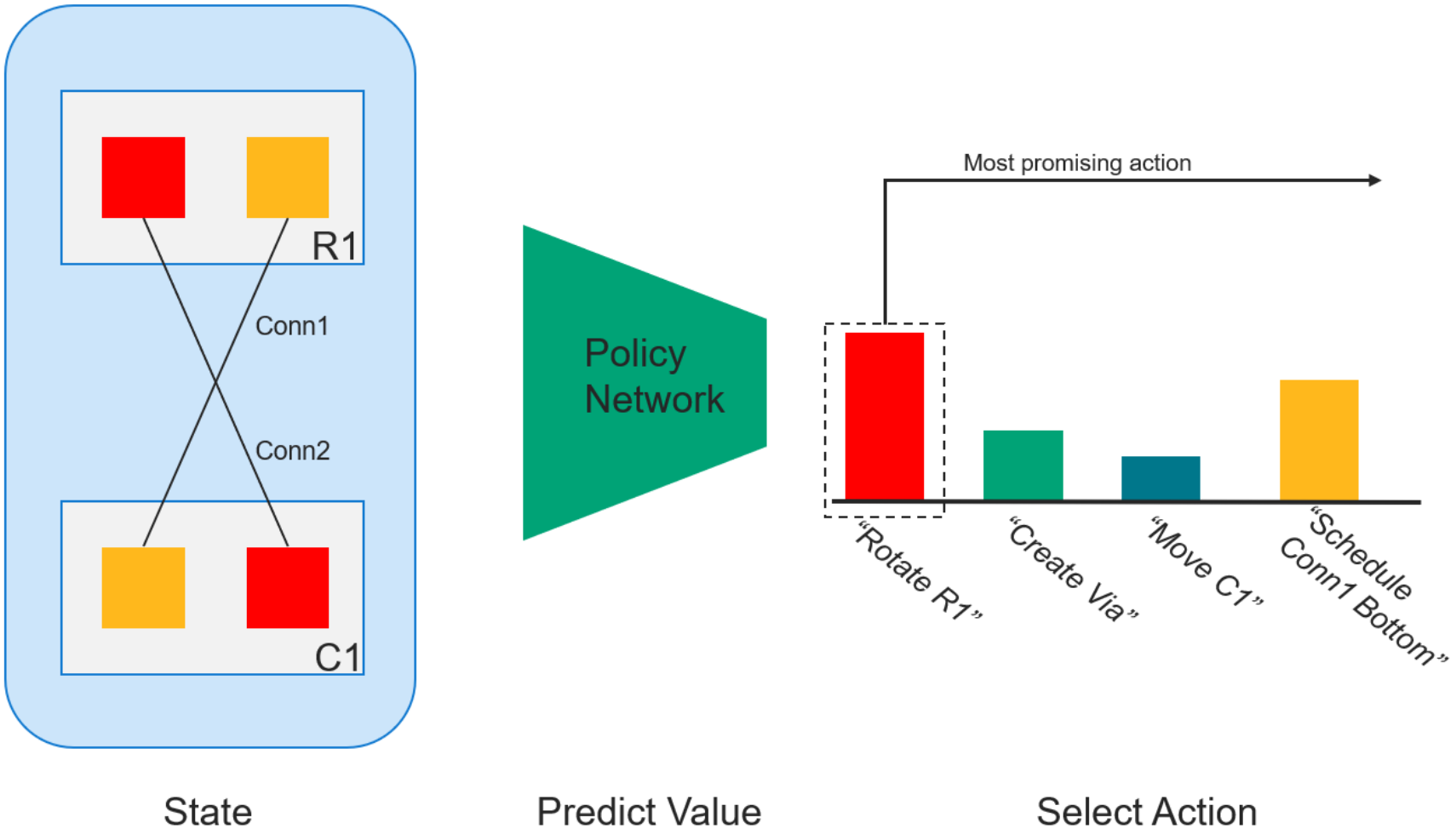

MCTS for PCB Design

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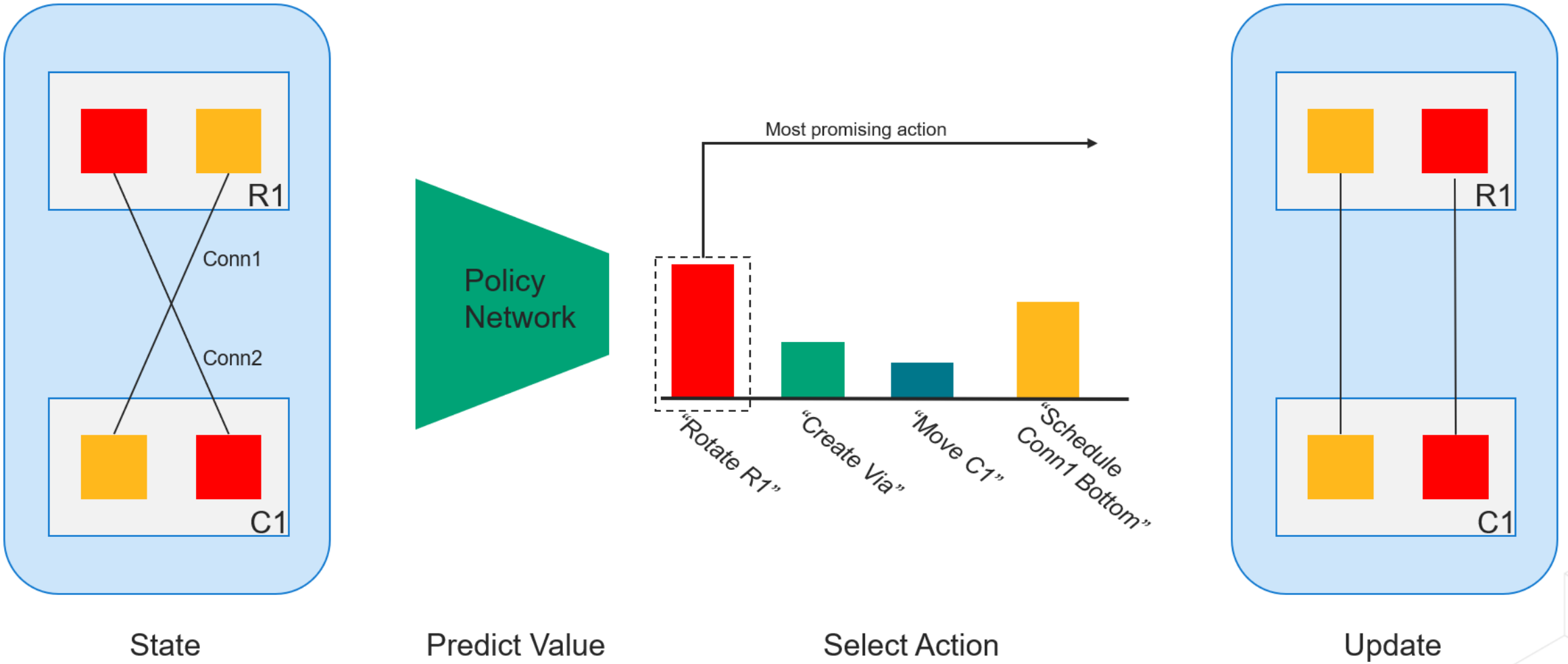
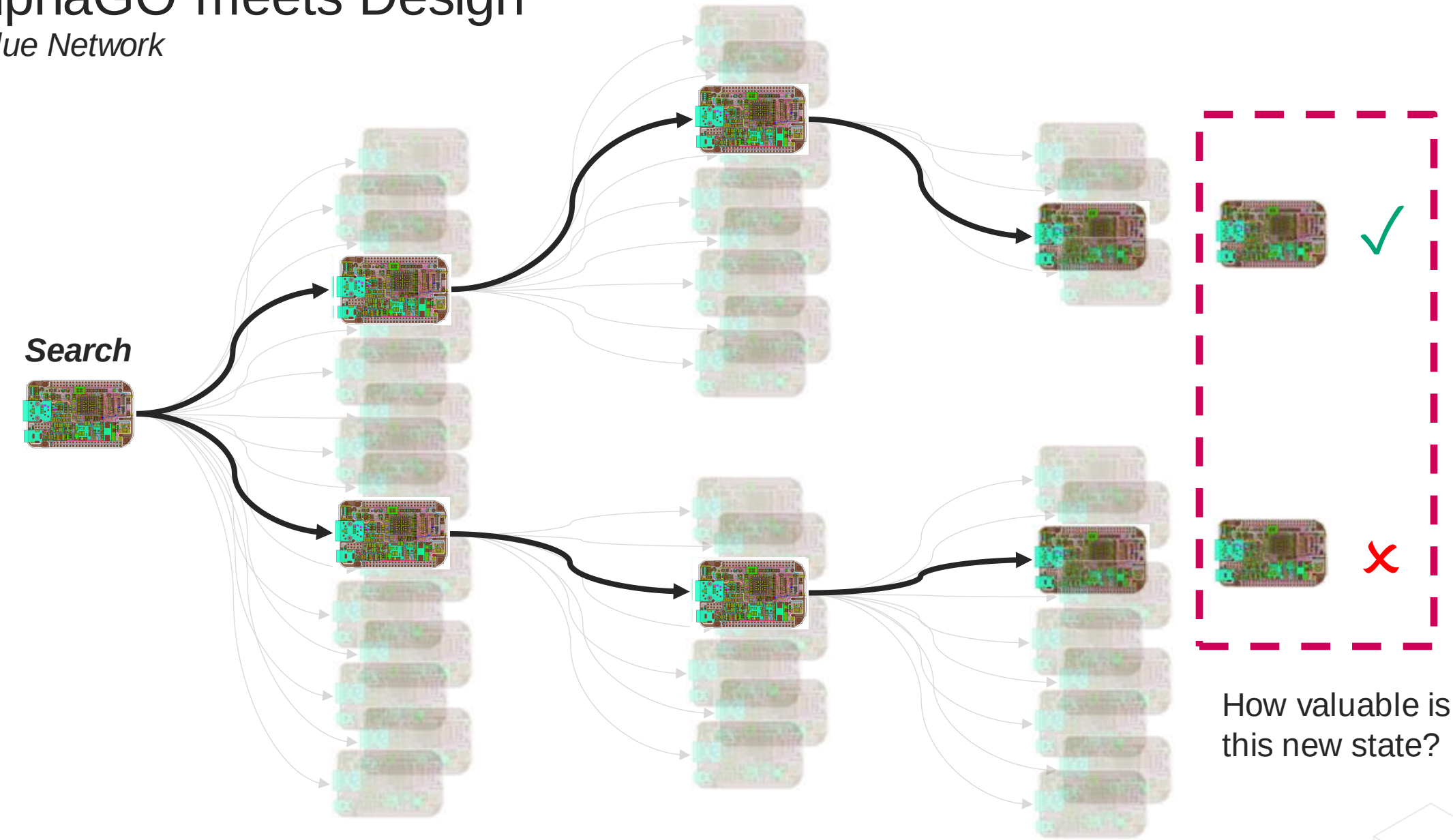


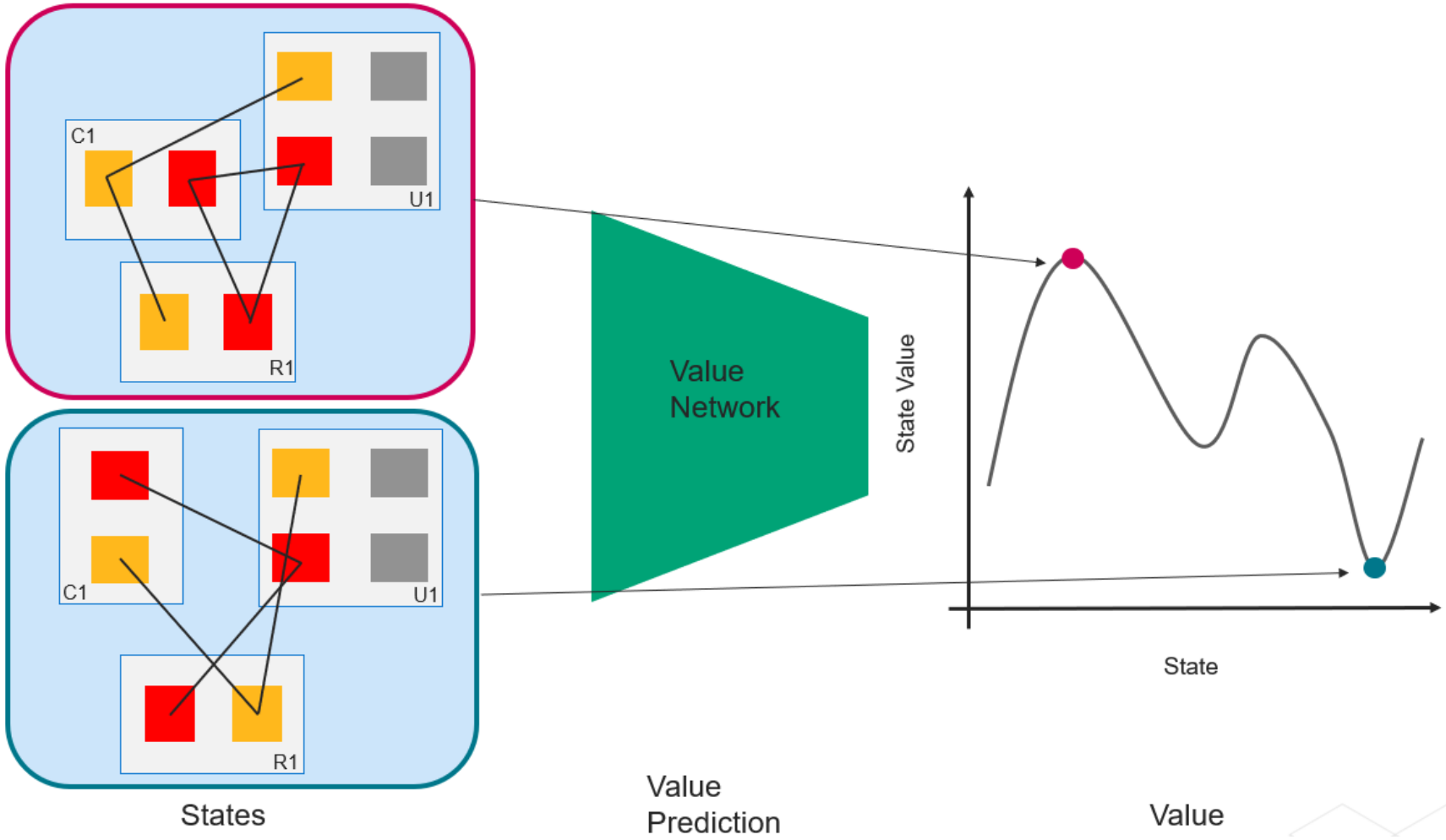
AlphaGO meets Design

Value Network



MCTS for PCB Design

Value Network



What problems can machine learning solve?

- *ML for prediction problems*

- *ML for design problems*

- *ML at scale*

Lessons in Scaling Laws

Let's dream a little bit

DALL·E 2 can create original, realistic images and art from a text description. It can combine concepts, attributes, and styles.

TEXT DESCRIPTION

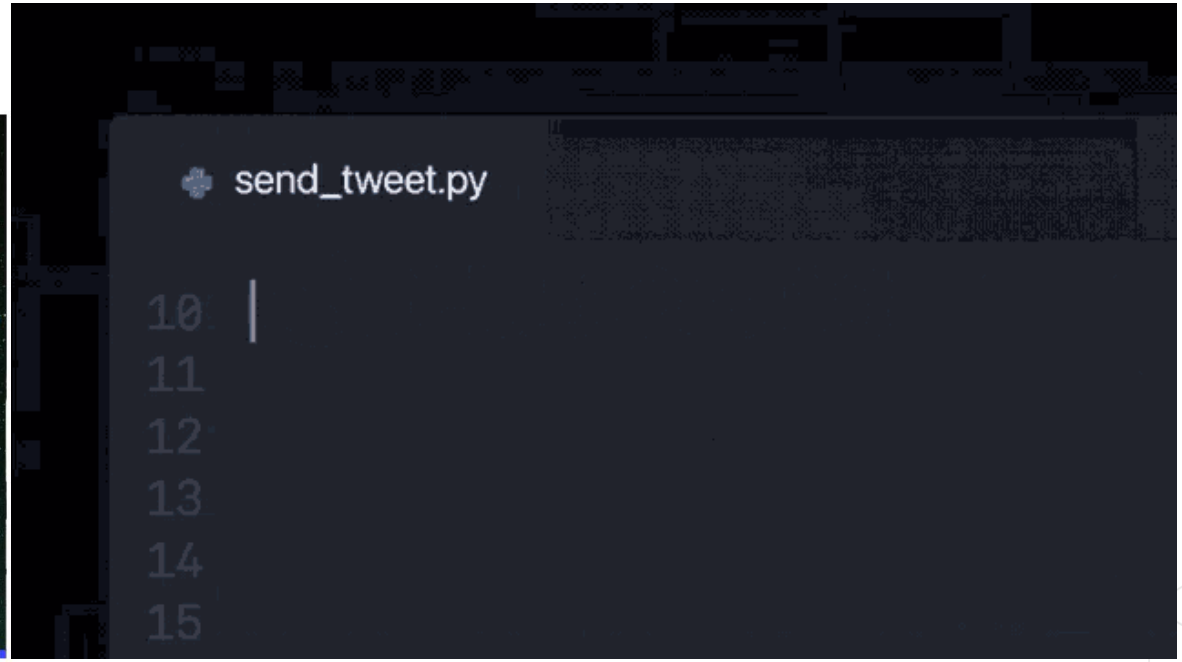
An astronaut Teddy bears A bowl of soup

riding a horse lounging in a tropical resort in space playing basketball with cats in space

in a photorealistic style in the style of Andy Warhol as a pencil drawing

→

DALL·E 2



https://openai.com/dall-e-2/

https://dev.to/thenomadevel/what-is-github-copilot-will-it-take-your-jobs--33p5

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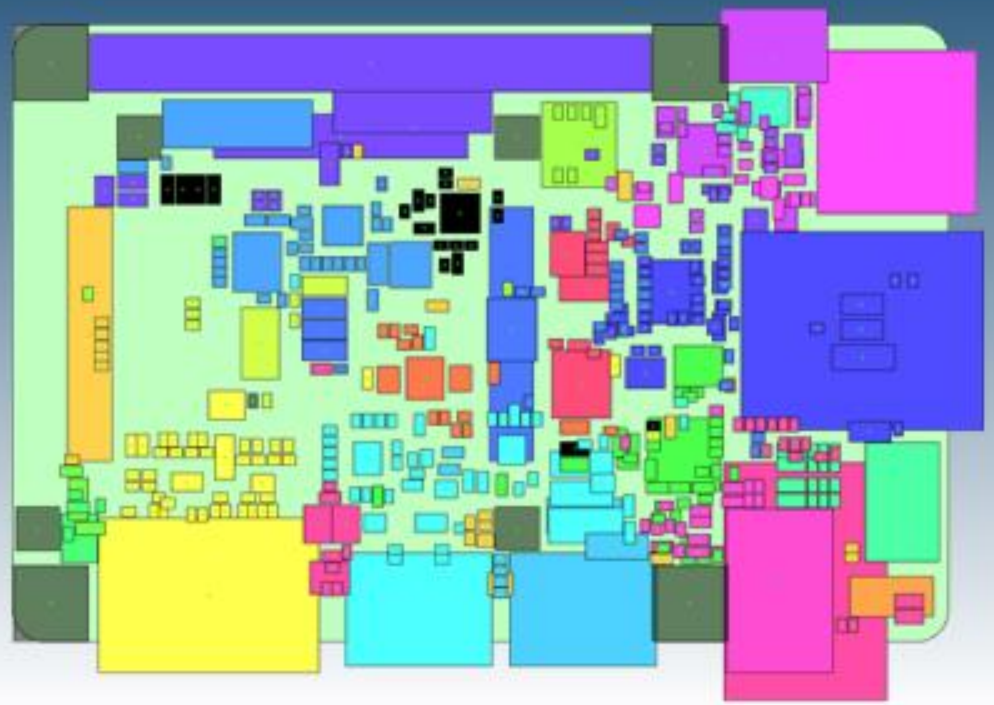
X AI

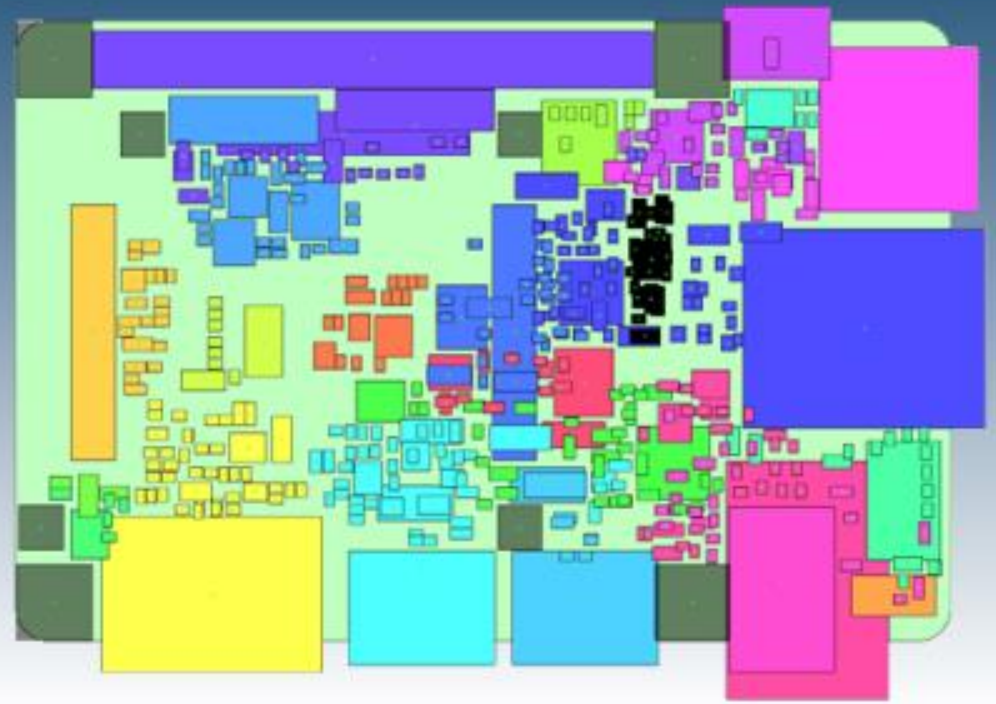
Artificial Intelligence to Reduce Time to Design PCBs – Google Coral Board

Human Placement



~ 3 days Placement

Allegro X: AI Clustering



75 minutes
14% better wirelength
Incremental setup time 15 mins

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