# CIRCA: Towards a Modular and Extensible Framework for Approximate Circuit Generation

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# Outline

- Motivation
- Related Work
  - Classification
  - Requirements & Goals
- The CIRCA Framework
  - Concept
  - Current State: Implementation & Exemplary Results
- Conclusion & Outlook

# Motivation

- Approximate Computing (AC) on circuit level
  - AC exploits gap between required and provided computational accuracy
  - Trade off computational accuracy against area, delay, or energy consumption
- Large approximation space for complex Circuits
  - Large amount of possible approximation candidates
  - Effects of approximations become non-intuitive
- Demand for an automated approximation process

# Related Work: Classification

| Category | SASIMI [1] | SALSA [2] | AIG RW [3] | ABACUS [4] | SCALS [5] | ASLAN [6] |
|---|---|---|---|---|---|---|
| Circuit Type | Input | | | | | |
| Input Model | | | | | | |
| Error Model | | | | | | |
| Search Method | Generation/synthesis | | | | | |
| AC Technique | | | | | | |
| Quality Assurance | | | | | | |
| Output | Output | | | | | |
| Output Model | | | | | | |
| Target Technology | | | | | | |
| Publicly Available | Availability | | | | | |

# Related Work: Classification

| Category | SASIMI [1] | SALSA [2] | AIG RW [3] | ABACUS [4] | SCALS [5] | ASLAN [6] |
|---|---|---|---|---|---|---|
| Circuit Type | Comb. | Comb. | Comb. | Comb. + seq.(?) | Comb. | Seq. |
| Input Model | Gate netlist | Gate netlist | Gate netlist/AIG | Behavioral HDL | Gate/LUT netlist | Structural HDL + annotations |
| Error Model | Error bound | Quality function | Error bound | #Iterations | Error bound | Quality Evaluation Circuit |
| Search Method | Heuristic (hill climbing) | - | Heuristic (greedy) | Heuristic (greedy) | Heuristic (Metropolis-Hastings) | Heuristic (hill climbing) |
| AC Technique | Substitute-and-Simplify | Approx. don't care | AIG re-writing | AST transforms | Logic transforms | Precision scaling |
| Quality Assurance | Testing | By construction | Formal verification | Testing | Testing | Formal verification |
| Output | Approx. circuit | Approx. circuit | Approx. circuit | Pareto front | Approx. circuit | Approx. circuit |
| Output Model | Gate netlist | Gate netlist | Gate netlist (AIG) | Behavioral HDL | Gate/LUT netlist | Structural HDL |
| Target Technology | Std. cell | Std. cell | Technology Independent | Std. cell | Std. cell/LUT-based | Std. cell |
| Publicly Available | - | - | Yes | Yes | - | - |

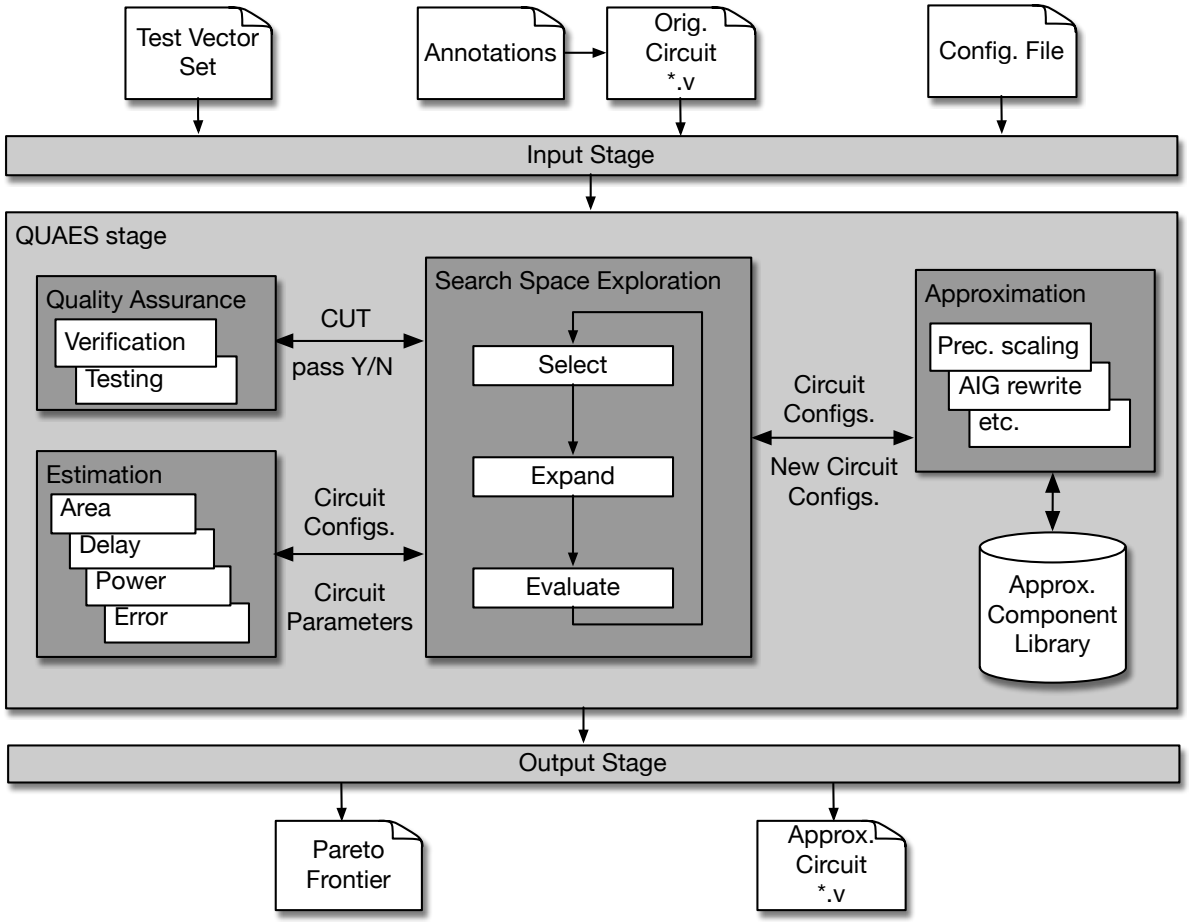
# Related Work: Requirements & Goals

- Requirements to a framework
  - Compatible ✔
  - Open-source O
  - General ✘
  - Extensible ✘
  - Modular ✘

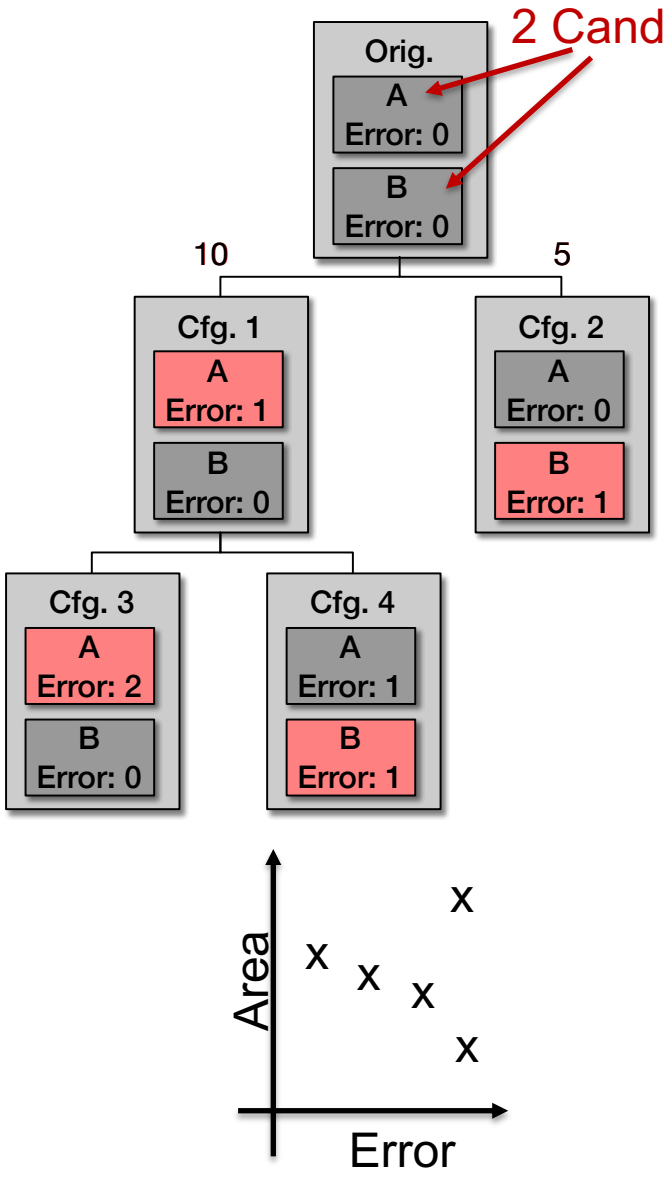
- Goal: Develop framework which satisfies these requirements

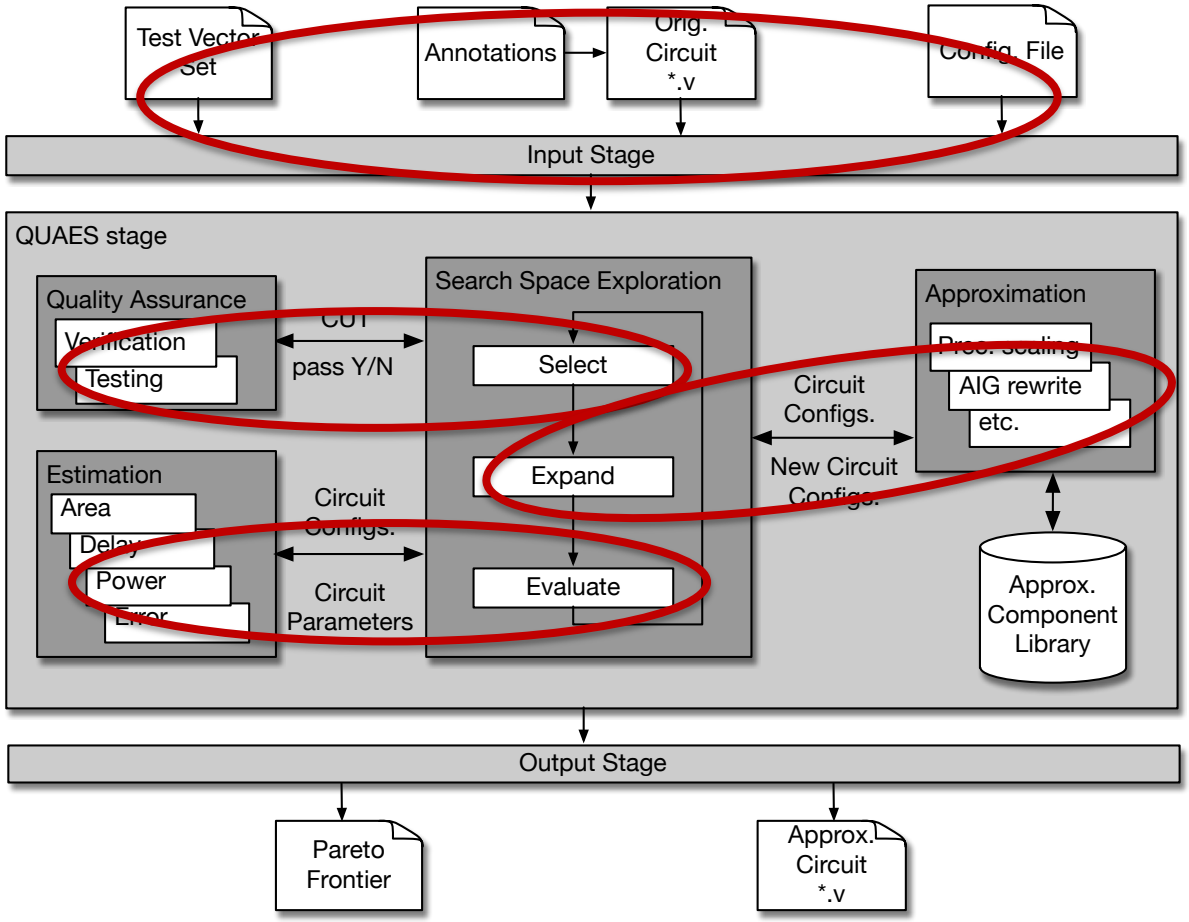
# CIRCA: Concept

- Pre-process input data
- Perform
  - Search
  - Quality assurance
  - Approximations
  - Estimate circuit parameters



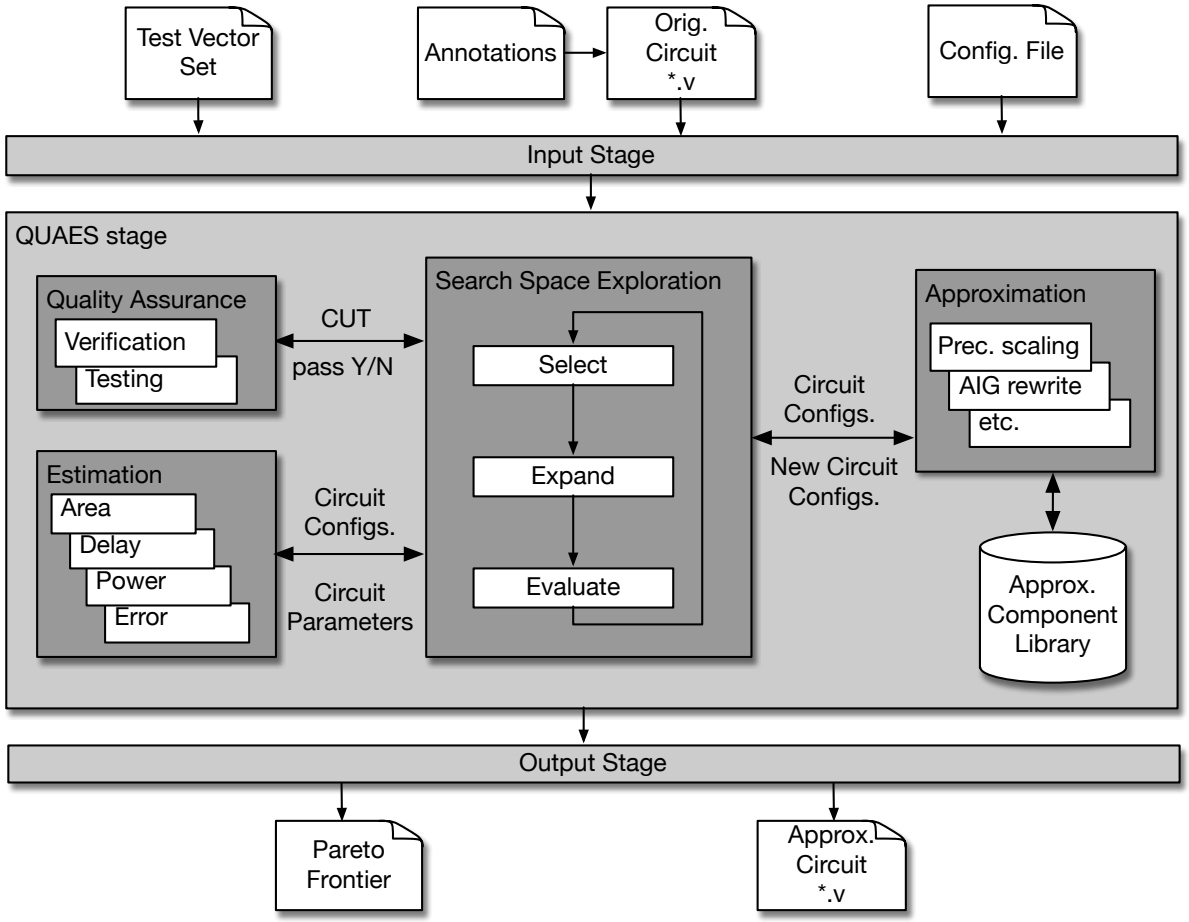
# CIRCA: Concept



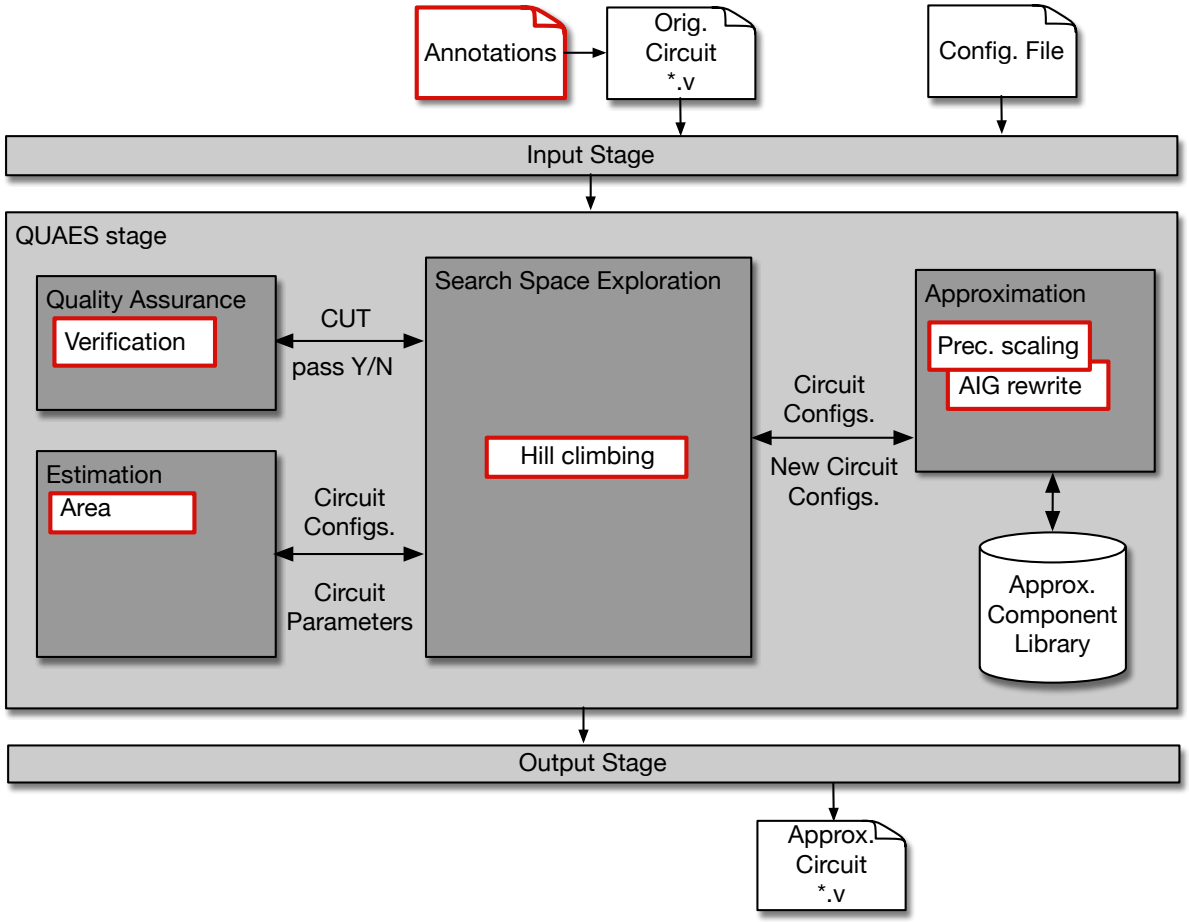
# CIRCA: Concept

- Input & Output stage ensure compatibility
- User configures the approximation process
- Independent blocks
  - Modular
  - Extensible
  - General



# CIRCA: Current State

- Hill climbing search
  - Heuristic considers hardware area of candidates individually
- Two approximation techniques
  - Precision scaling
  - AIG re-writing
- Formal verification assures quality
  - Inductive solver used from ABC [7]
  - Support for combinational and sequential circuits

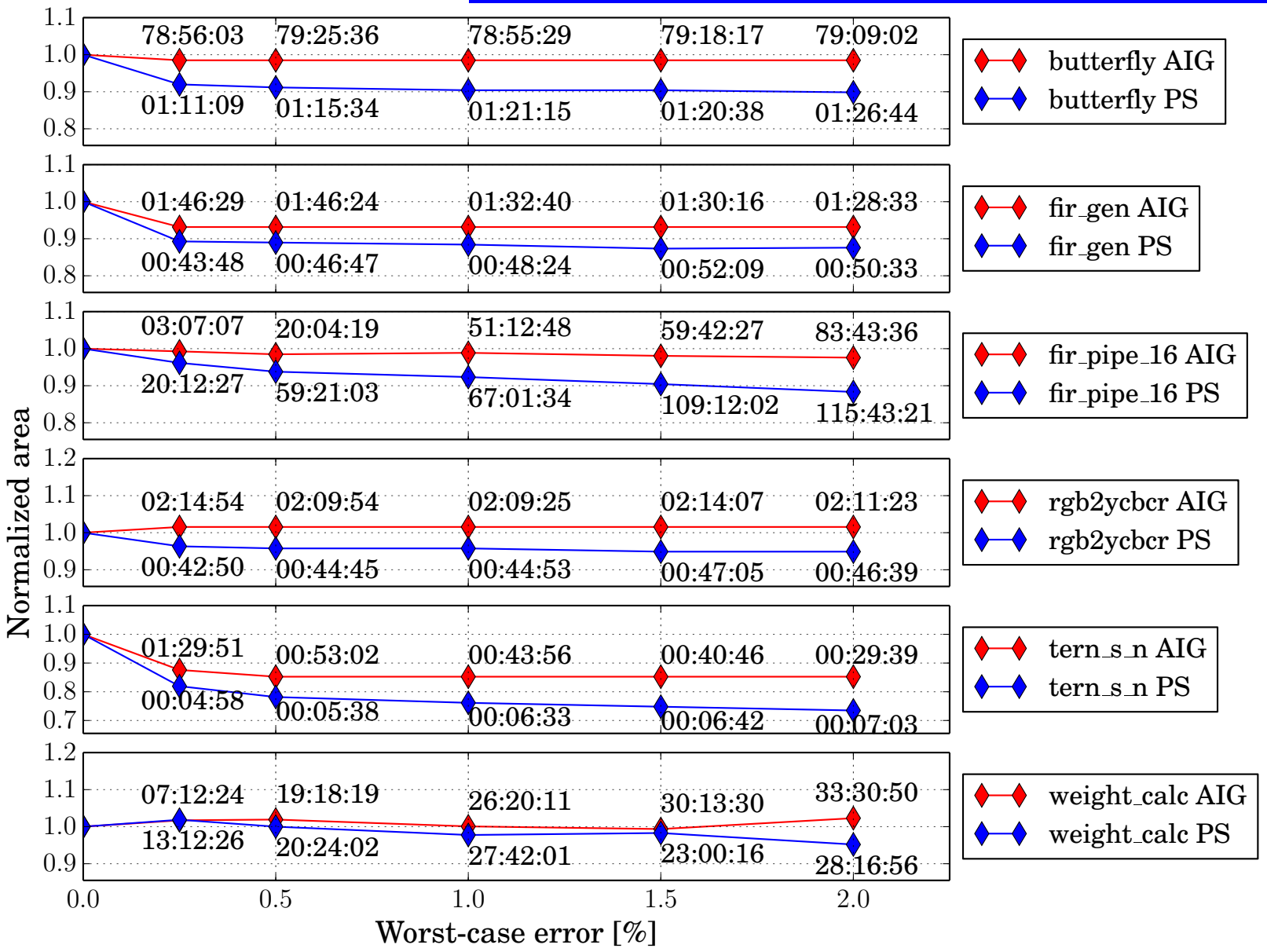


# CIRCA: Exemplary Results

| Circuit Name | Description | #4-LUTs | #Candidates |
|---|---|---|---|
| butterfly [8] | Operation used in FFT | 7221 | 8 |
| fir_gen [8] | FIR filter 4-tap | 5438 | 7 |
| fir_pipe_16 [9] | FIR filter 16-tap | 8768 | 23 |
| rgb2ycbcr [10] | Color-space transformation | 4527 | 5 |
| ternary_s_n [10] | Adder tree | 1483 | 4 |
| weight_calc | Industrial scale | 1872 | 4 |

- ABC used to estimate area
- 10 runs per benchmark circuit
  - Varied worst-case error from 0.25% to 2.0%
  - Use precision scaling & AIG RW
  - Report for hardware area & runtime of CIRCA

# CIRCA: Exemplary Results



# Conclusion & Outlook

- Analyzed existing frameworks
  - Identified & elaborated on requirements
- Presented concept for CIRCA
  - Modular and extensible framework
  - Showed current state & initial experimental results
- CIRCA enables comparing studies in Approximate Computing

- Continue implementation
  - Investigate other search methods and approximation techniques, e.g., A* and circuit carving [11]
  - Implement other error metrics, e.g., average case error
  - Connect to back-end synthesis tool, e.g., Synopsys Design Compiler
- Make CIRCA open-source
- Create an AC benchmark circuit set
- Develop front-end to automatically identify candidates

**Thank you for your attention!**

**Questions?**

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