Evolutionary Multiobjective Design targeting a FPTA

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Outline

- Motivation
- The multiobjective concept
- ISPAES Algorithm
- Experiments
- Conclusions

Motivation

- Most problems have several goals and constraints
- Most evolutionary applications comprise all goals into a single fitness function:

  $f(x,y,z\ldots w)=goals + K(constraints)$

  K: penalization(static or dynamic)

- Alternatives: use multiobjective approach

Motivation

- Evolutionary algorithms need to be enhanced with a mechanism for constraint handling.

- Also, need to capture the multiobjective concept.

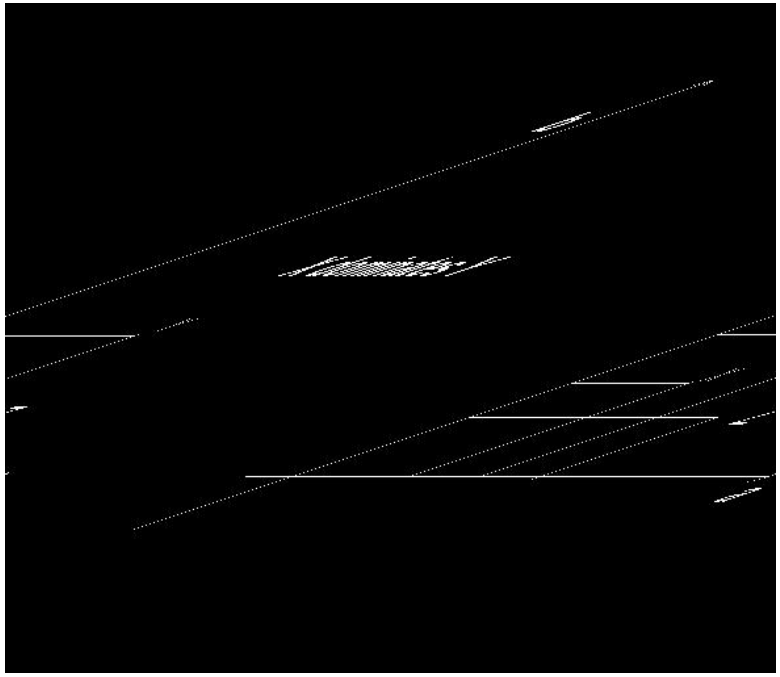
The multiobjective concept

- Pareto optimality criteria relies on Pareto dominance

Xa < Ya and Xb < Yb

Informal definition:

At least one component is better, and the other components are not worst



The multiobjective concept

- Dominance on space of functions, same idea

$F(x,y)=\langle f1(x,y),f2(x,y)\rangle$

$F(p,q)=\langle f1(p,q),f2(p,q)\rangle$

(x,y) dominates (p,q) IF

$f1(x,y) < f1(p,q)$ and $f2(x,y) <= f2(p,q)$

OR

$f1(x,y) <= f1(p,q)$ and $f2(x,y) < f2(p,q)$

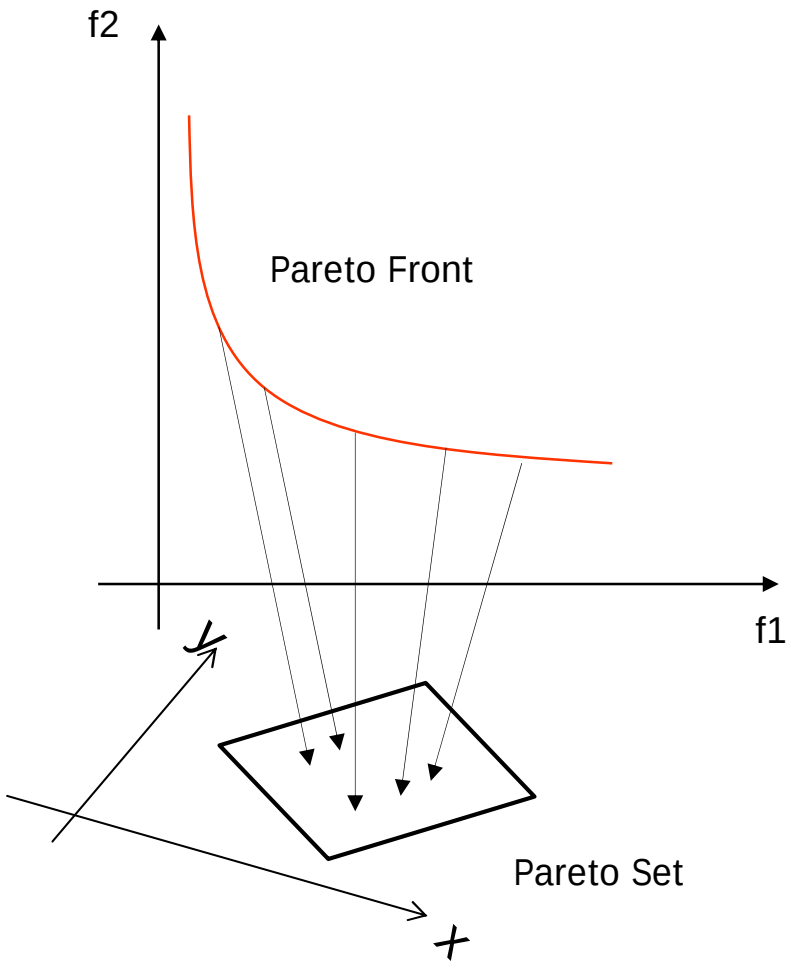
The multiobjective concept

- Pareto Set:

  The non-dominated set of vectors in the space of decision variables

  Pareto Front:

  The projection of Pareto Set on the space of functions



Constraint Handling

- Treat constraints as objectives, then solve the problem as a multiobjective optimization one, without constraints.
- Selection operator now based on Pareto dominance
- Selection rules are:

  Feasible-Nonfeasible -> feasible wins

  Feasible-Feasible -> non dominated wins

  Nonfeasi.-Nonfeasi. -> less constraint violation wins

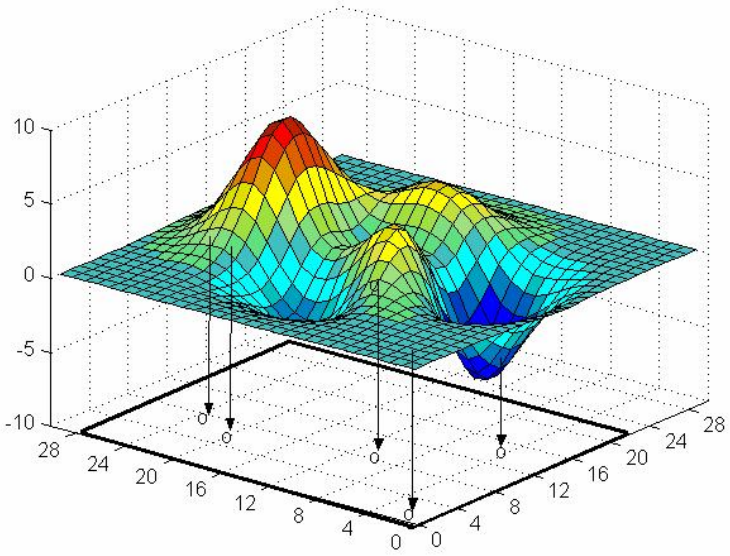
Improving Constraint Handling

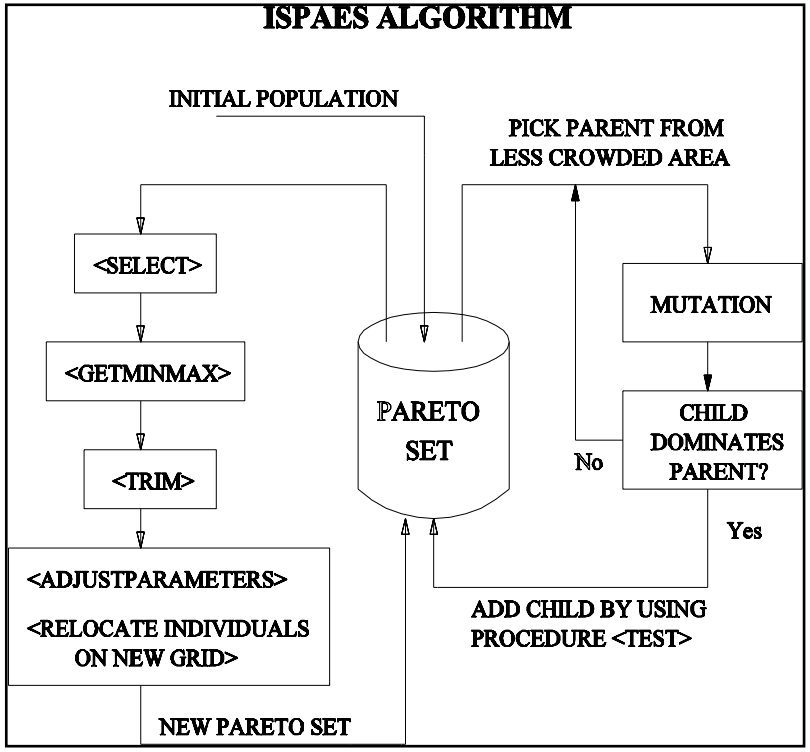
- Keeping diversity is essential to avoid premature convergence => poor exploration
- Selection operator must promote promisory individuals
- A combination of feasible and unfeasible individuals is desirable
- Dispersion on the Pareto front becomes an issue

ISPAES Algorithm

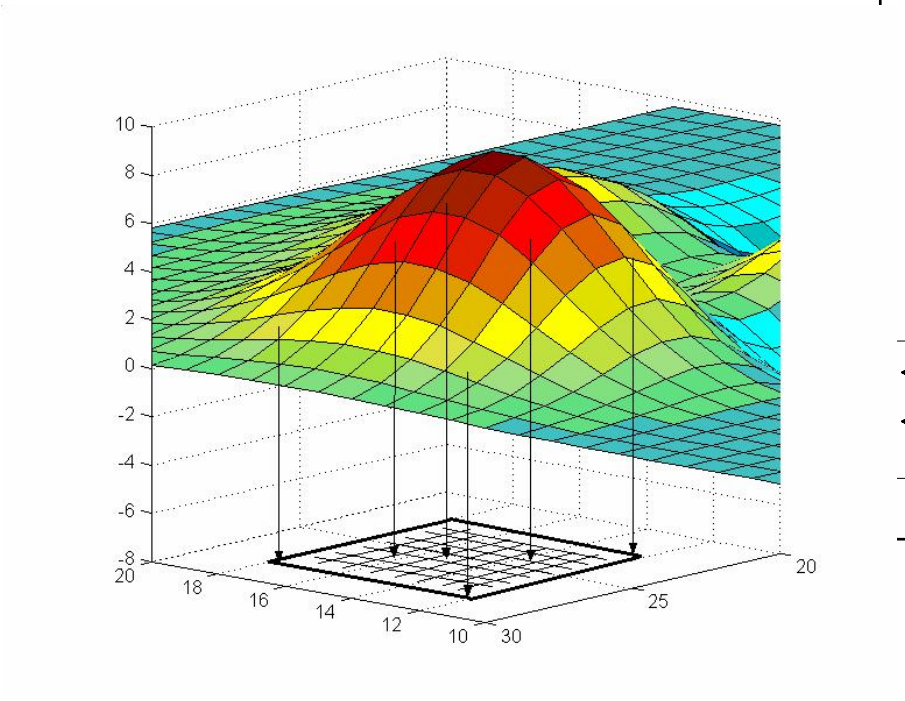
- Inverted Shrinkable Pareto Archived Evolution Strategy
- (1+1)-ES
- External file stores the current Pareto Set
- Adaptable greed keeps diversity
- Pareto dominance selection
- Search space is bounded and reduced over generations
- Selection does not pick good individuals, but it removes bad ones => reduces selection pressure, so helps to keep diversity

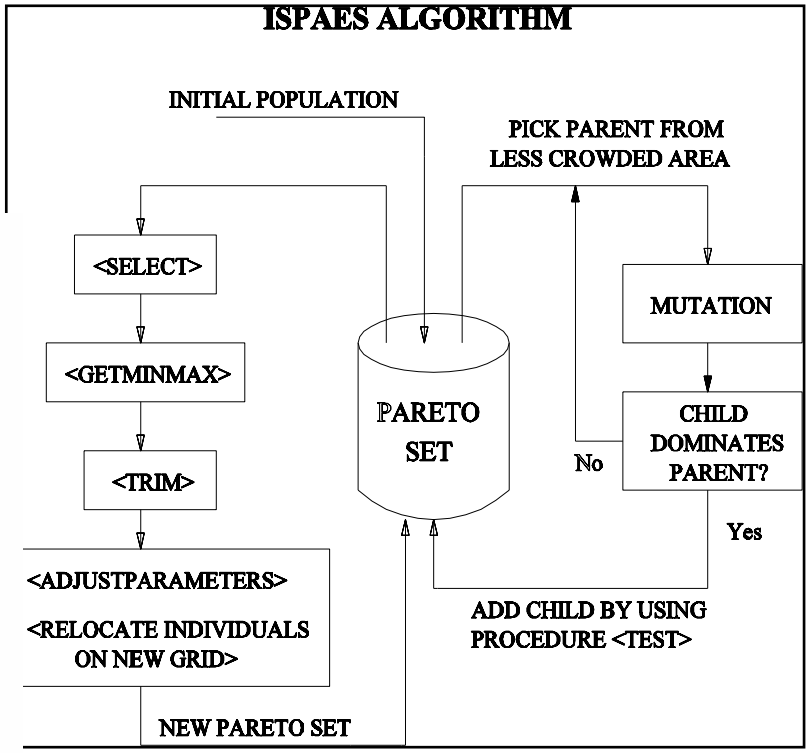
ISPAES Algorithm





ISPAES Algorithm





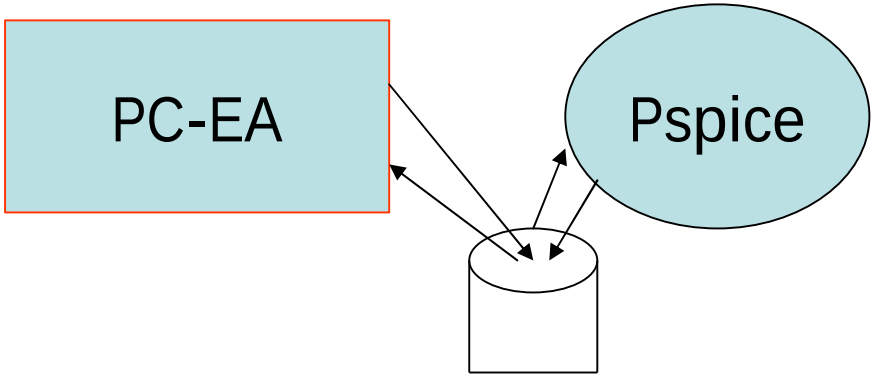
ISPAES: EE’control variables

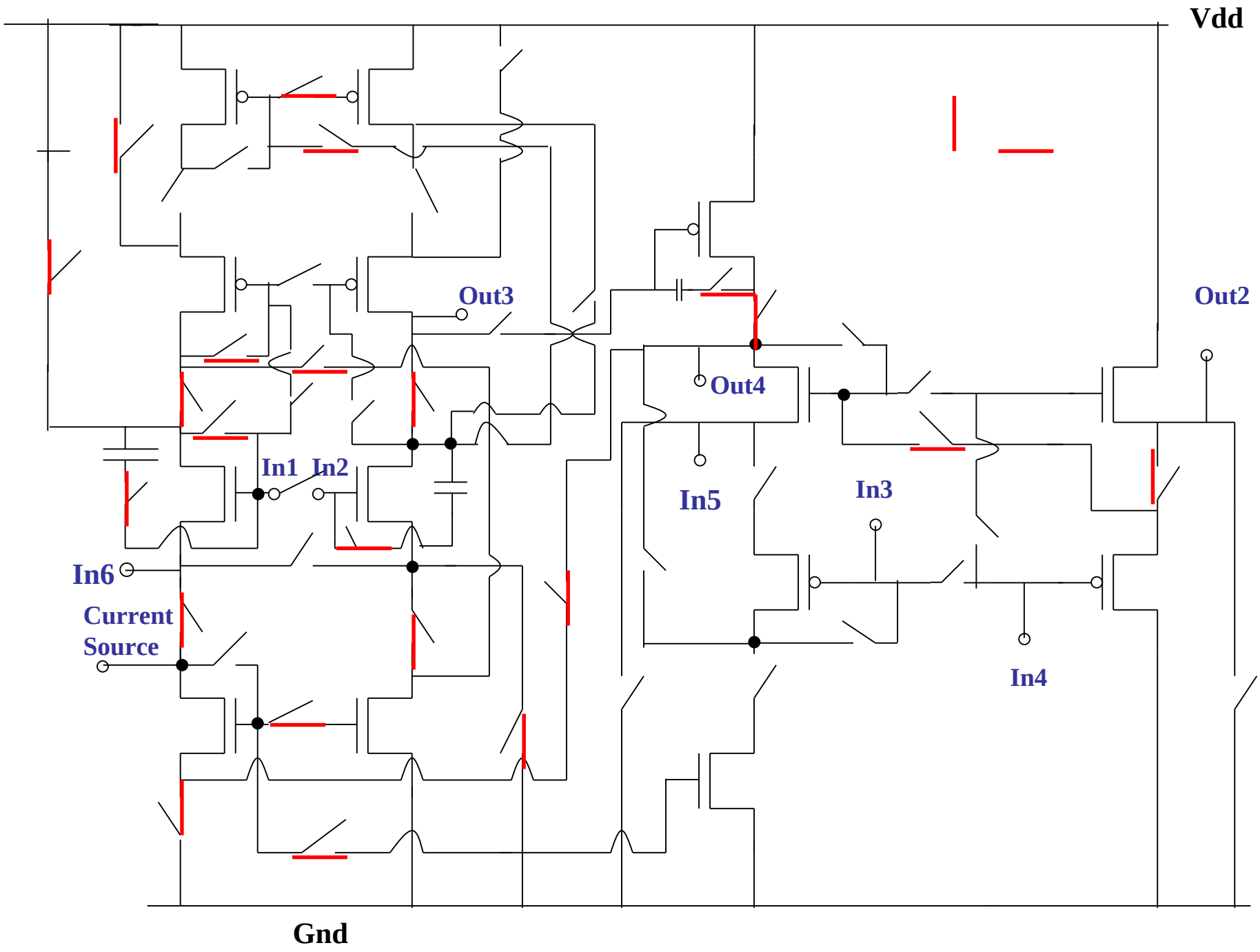
- Control variables can be adjusted to deal with real or integer objective variables
- Mutation of variable control sÂfor integer objective variables:

```
if (random() <0.45) sK= sK+1;
   else sý= sý-1;
```

The target FPTA

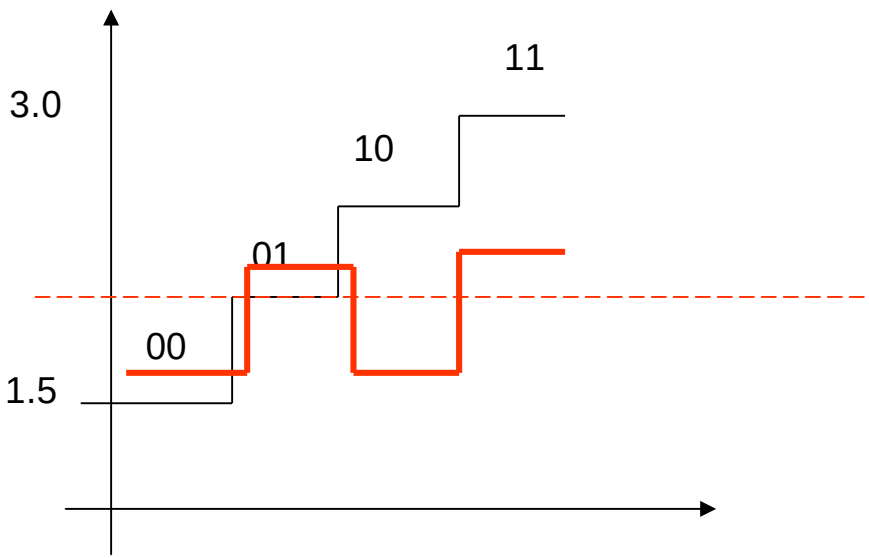
- Extrinsic evolution




Vdd
Out3
Out2
Out4
In1
In2
In5
In3
In6
Current
Source
In4
Gnd

Experiment 1: LSB for a 4-steps ramp

- Input/Output



Multiobjective ISPAES

$$O_1 = OV_{in=1.5v} + OV_{in=2.5v} - OV_{in=2.0v} - OV_{in=3.0v} < 0$$

$$\begin{aligned} C_1 &= OV_{in=1.5v} - 2.0 < 0 \\ C_2 &= OV_{in=2.5v} - 2.0 < 0 \\ C_3 &= 2 - OV_{in=2.0v} < 0 \\ C_4 &= 2 - OV_{in=3.0v} < 0 \end{aligned}$$

Single Objective GA

$$fitness = (VOL - VZH) * 1000$$

Experiment 1: LSB for a 4-steps ramp

Input Ramp	GA	ISPAES
1.5v	2.6571v	1.9601v
2.0v	2.7081v	3.0914v
2.5v	2.6700v	1.9394v
3.0v	2.7198v	3.1650v

Experiment 2: 2-Bit ADC

Multiobjective approach

2 objectives

$$
\begin{aligned}
O_1^{LSB} &= OV_{in=1.5v}^{LSB} + OV_{in=2.5v}^{LSB} \\
&\quad -OV_{in=2.0v}^{LSB} - OV_{in=3.0v}^{LSB} < 0 \\
O_2^{MSB} &= OV_{in=1.5v}^{MSB} + OV_{in=2.5v}^{MSB} \\
&\quad -OV_{in=2.0v}^{MSB} - OV_{in=3.0v}^{MSB} < 0
\end{aligned}
$$

8 constraints

$$
\begin{aligned}
C_1 &= OV_{in=1.5v}^{LSB} - 2.0 < 0 \\
C_2 &= OV_{in=2.5v}^{LSB} - 2.0 < 0 \\
C_3 &= 2 - OV_{in=2.0v}^{LSB} < 0 \\
C_4 &= 2 - OV_{in=3.0v}^{LSB} < 0 \\
C_5 &= OV_{in=1.5v}^{MSB} - 2.0 < 0 \\
C_6 &= OV_{in=2.0v}^{MSB} - 2.0 < 0 \\
C_7 &= 2 - OV_{in=2.5v}^{MSB} < 0 \\
C_8 &= 2 - OV_{in=3.0v}^{MSB} < 0
\end{aligned}
$$

Experiment 2: 2-Bit ADC

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Input Ramp	GA-LSB	ISPAES-LSB
1.5v	1.9311v	1.9370v
2.0v	1.9512v	2.015v
2.5v	1.9446v	1.3323v
3.0v	2.0813v	3.1183v

Input Ramp	GA-MSB	ISPAES-MSB
1.5v	2.1522v	1.6558v
2.0v	2.4962v	1.7497v
2.5v	2.8645v	2.3604v
3.0v	3.2514v	2.6551v

Conclusions

- Real life problems need a multiobjective solver with constraint handling
- Multiobjective approach allows to capture the design specification and goals.
- Better results could be obtained than with a single fitness function
- Evolutionary algorithms need a constraint handling mechanism

THANK YOU