Epistatic Genetic Algorithm for Test Case Prioritization ♪

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TCP

The Test Case Prioritization Problem. *Given: T, a test suite; PT, the set of permutations of T; f, a function from PT to the real numbers*.

Problem: *Find* $T' \in PT$ *such that*

$$(\forall\, T'' (T'' \in PT)\ (T'' \neq T')\ [f(T') \geq (T'')].$$

NP-Hard

Different function f, which can be referred to as **fitness function**, corresponds to different objectives.

Zheng Li, Harman, M, Hierons, R.M. ***Search Algorithms for Regression Test Case Prioritization***. IEEE Transactions on Software Engineering, 2007, 33(4):225 - 237.

TCP

APSC(Average Percentage of statement coverage) is one of the most widely used function f.

$$\text{APSC} = 1 - \frac{TS_1 + TS_1 + \ \dots + TS_M}{NM} + \frac{1}{2N}$$

N : the number of test cases

M : the number of code lines

TS_i : the id of test case that first covers statement i.

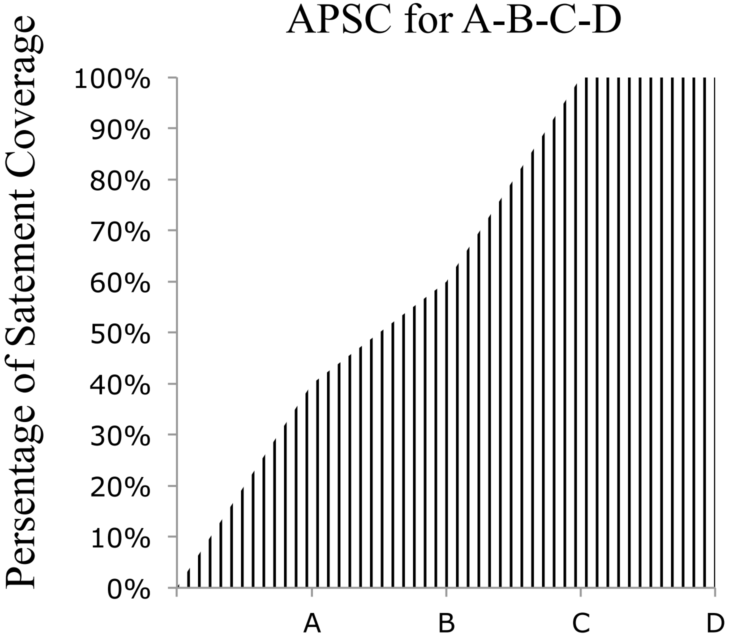
AP*C

Zheng Li, Harman, M, Hierons, R.M. ***Search Algorithms for Regression Test Case Prioritization***. IEEE Transactions on Software Engineering, 2007, 33(4):225 - 237.

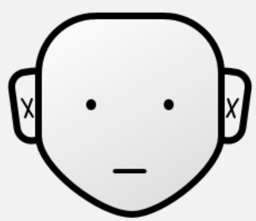
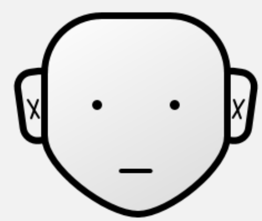
TCP

Test Case	Statement				
	1	2	3	4	5
A		X		X	
B		X	X		
C	X			X	X
D	X		X		

The area filled with straight lines is the APSC for A-B-C-D



Epistasis in biology

	Gene for blond hair	Gene for red hair
No gene for baldness	 Blond hair	 Red hair
+ Gene for baldness	 Bald	 Bald

Epistasis in GA

- The influence of a gene on the fitness of an chromosome depends on what gene values are present elsewhere.

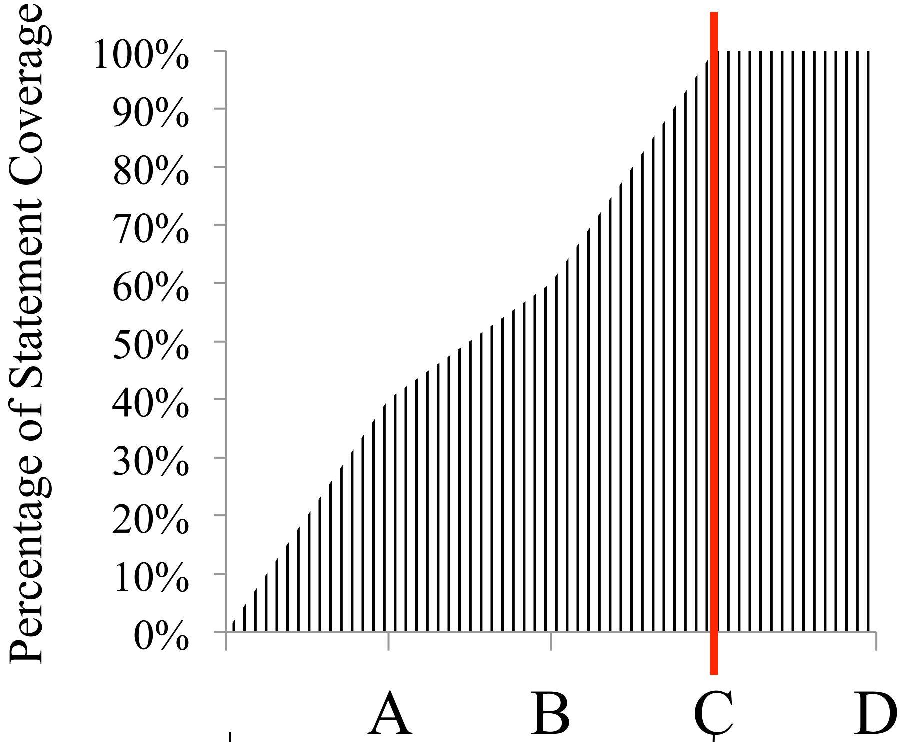
- If a small change is made to one gene we expect a resultant change in chromosome fitness. This resultant change may vary according to the values of other genes.

Epistasis effect

- **Little epistasis :**
  - Fitness is affected by each gene independently.
  - Optimization becomes gene-wise maximization.

- **High epistasis:**
  - Too many genes are dependent on other genes.
  - Good gene segment are long and of high order.
  - Hard to solve.

Epistasis in TCP



The area filled with straight lines is the APSC for A-B-C-D

The value of APSC **only** depends on this segment of test cases.

Epistasis in TCP

Epistatic Test Case Segment (ETS) : Given a permutation of all test cases in a test suite, the epistatic test case segment is a test cases segment which starts from the first test case in the execution sequence and ends with the test case that first reaches the maximum value of the test object.

The value of APSC **only** depends on this segment of test cases.♪

Epistasis in TCP

- The power of GA arises from crossover.
- Crossover is the main way to reproduce new individuals for GA.

How to adapt crossovers to TCP
under the guidance of ETS?

Epistasis in TCP

Traditional Crossover

Unware of ETS

Epistatic Crossover for TCP

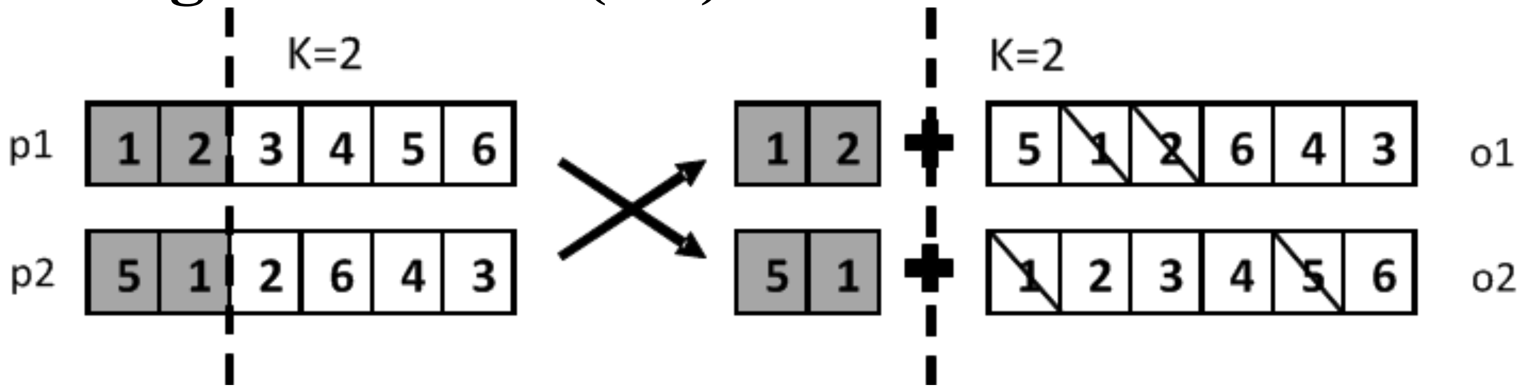
Pay more attention to ETS instead of the whole chromosome

TCP & GA

- Permutation Encoding is used. And the id of test cases are Unique in this encoding.
- A sequence of test cases is encoded as a chromosome.
- Use APSC as the fitness function and the value of APSC is only subject to ETS.

One-point crossover

- **Single crossover(SC)**

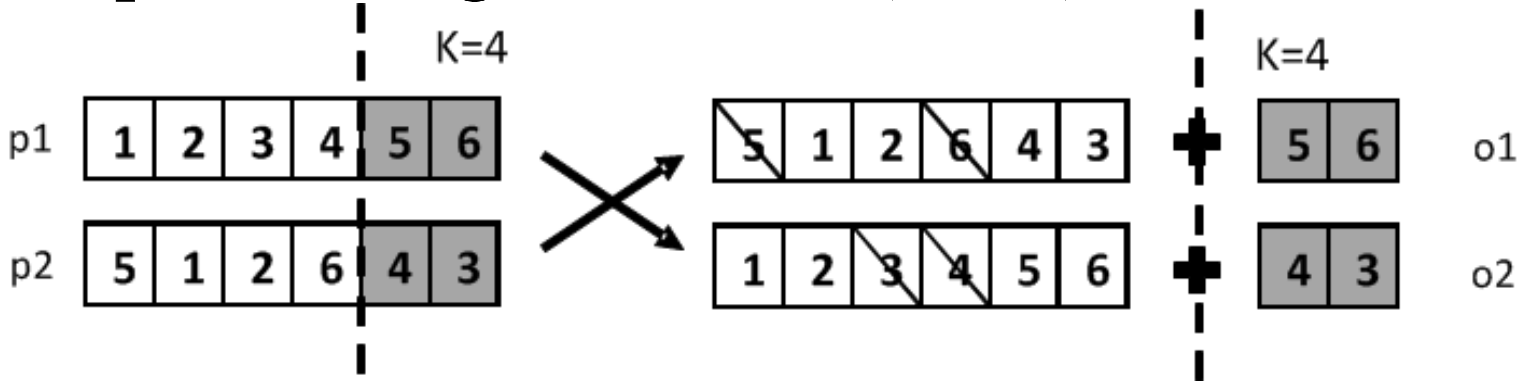


Problems:

- If cut point is out of ETS, the fitness of offspring and one parent will be just the same.
- With more iterations of GA, ETS tends to be shorter, accordingly the possibility that cut point is out of ETS.

One-point crossover

- **Epistatic single crossover(E-SC)**



Difference:

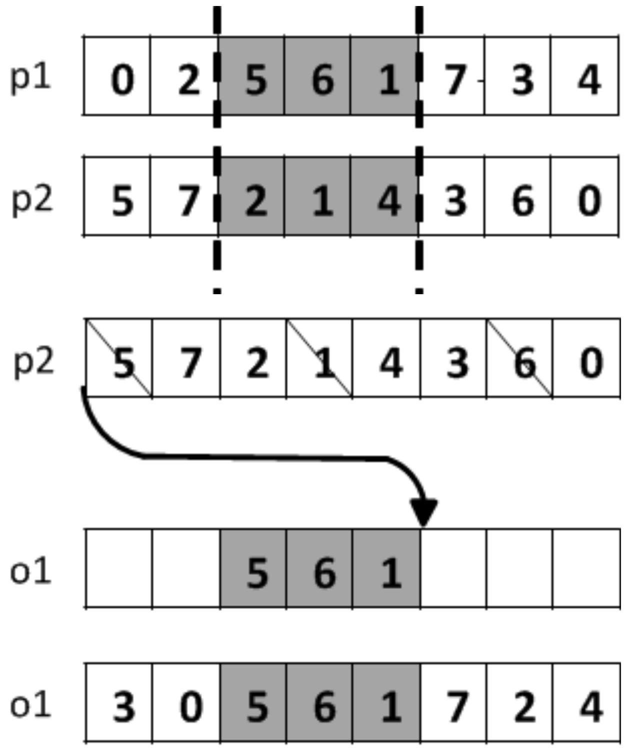
- SC preserves the first k elements of parents, while E-SC varies the first k elements of parents.

Advantage:

- The possibility of changing ETS becomes higher.♪

Two-point crossover

- **Order crossover(Ord)**



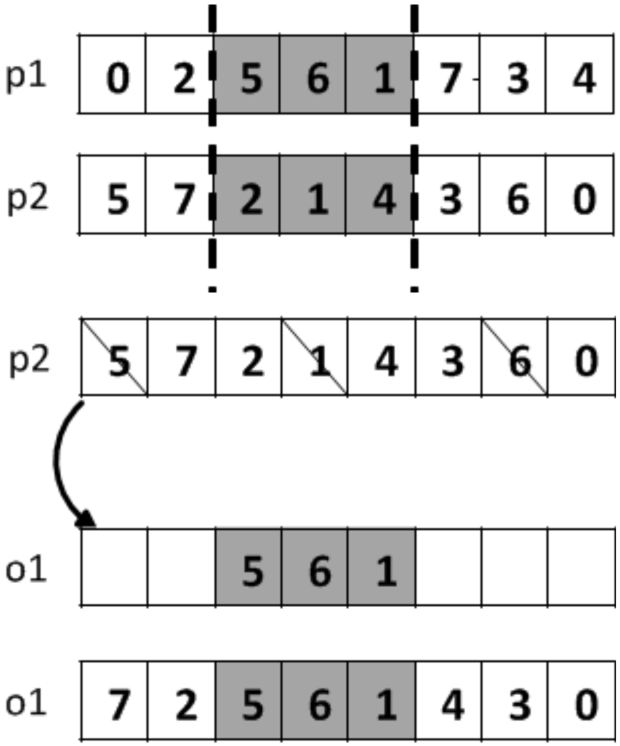
Ord

Problems:

- The genes constructing ETS for offspring mostly come from the later genes of the parent, rather than from the ETS in parent.

Unlikely to inherit good genes from parent.

- **Epistatic order crossover(E-Ord)**



E-Ord

Difference:

- The start position for the rest genes copied from p2.

Advantage:

- More likely to inherit good genes within ETS from parent.

Epistasis in TCP

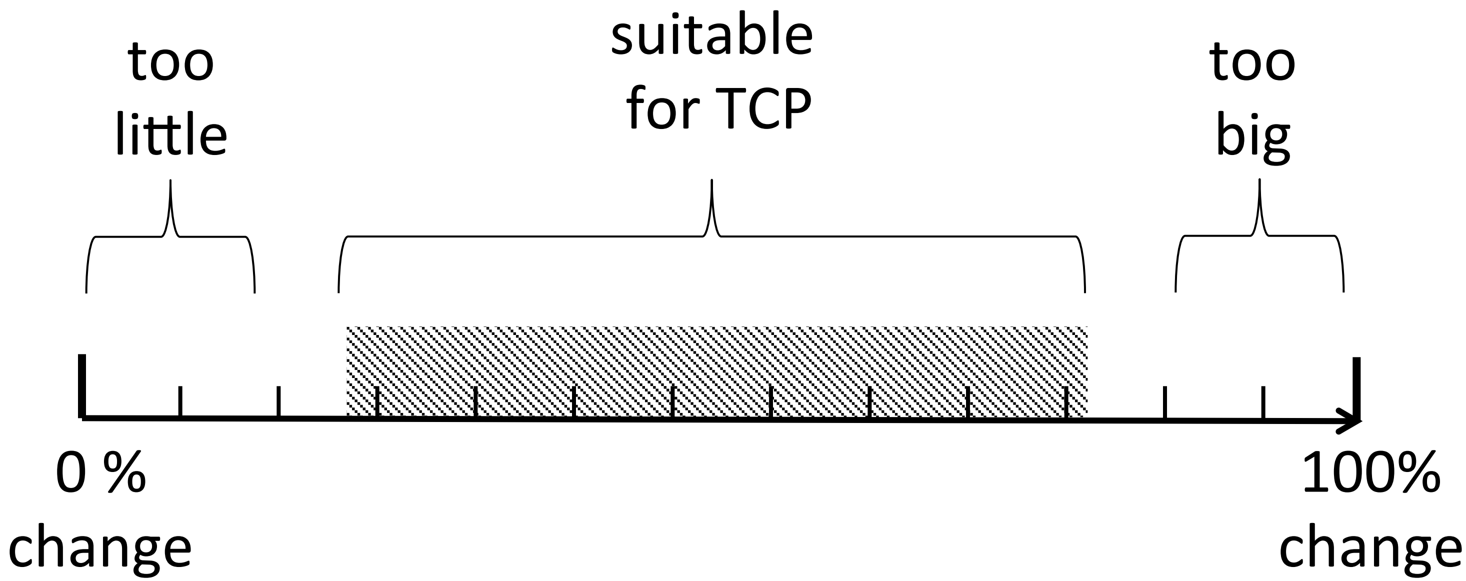
- **What's the scale of variation in ETS should occur?**

Too little:

Predominant → More predominant → Premature of GA

Too much : The lost inheritance of good ETSes.♪

Epistasis in TCP



The change scale of ETS

Research questions

- Does the epistatic crossovers outperform the original crossovers in effectiveness for TCP?
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- Does the epistatic crossovers outperform other two-point crossovers in efficiency for TCP?

Experiment

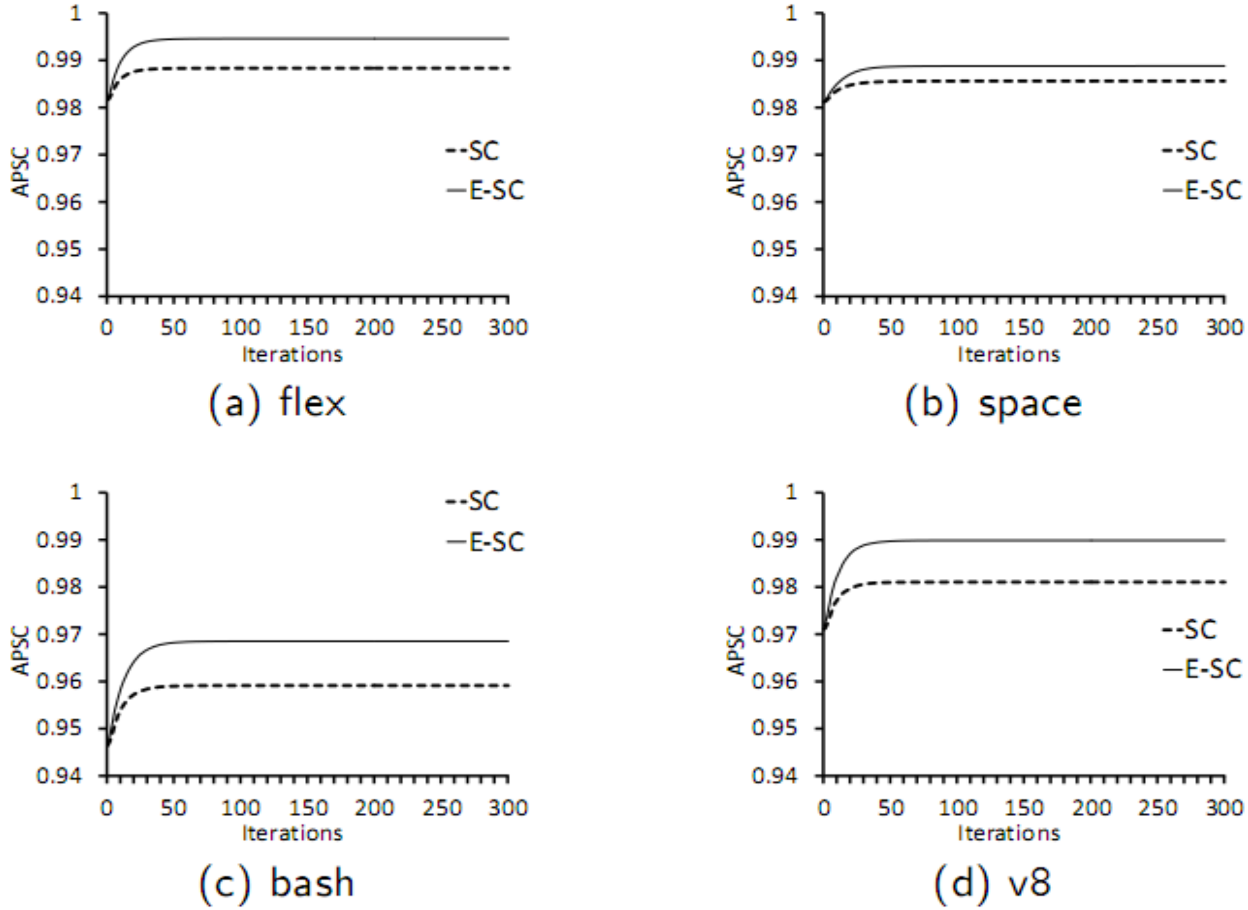
Termination A: fixes the number of iterations.♪
Termination B: terminate GA while the fitness of APSC reaches a stable status.
♪

Experiment	Setup
1A	SC vs E-SC with termination A
1B	SC vs E-SC with termination B
2A	Ord vs E-Ord with termination A
2B	Ord vs E-Ord with termination B
3A	E-Ord vs PMX with termination A
3B	E-Ord vs PMX with termination B

Experiment

Subject	SLOC	test suite size		
		min	max	average
flex	3016	1047	1470	1350.17
space	3815	1208	3229	1894.29
bash	6181	764	1467	1063.17
v8	59412	2564	6159	3909.15

Experiment 1A



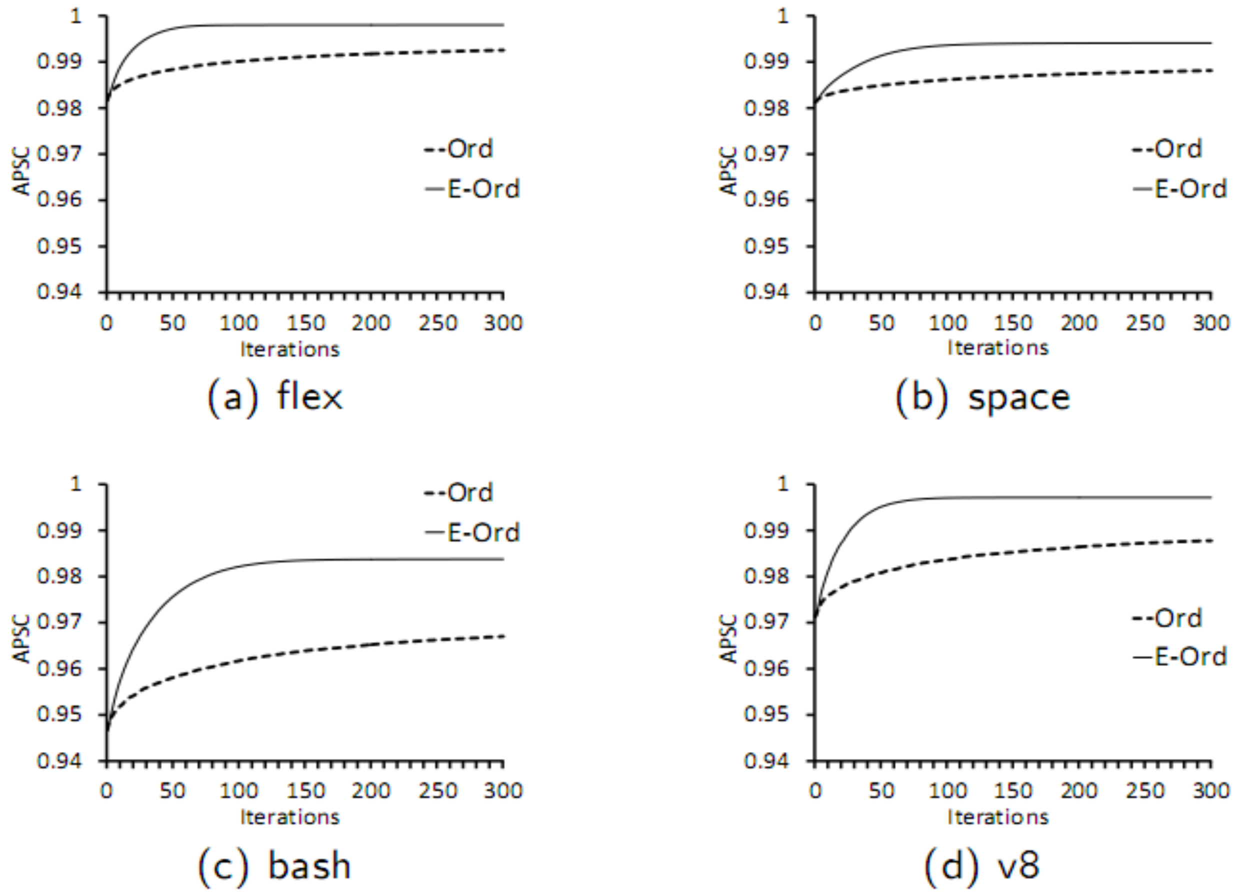
The average APSC values with the increasing iterations in GA with SC and E-SC for four subjects respectively

Experiment 1B

The average iterations and average final APSC with SC and E-SC:

Subject	SC			E-SC		
	avg iters	avg APSC	variation	avg iters	avg APSC	variation
flex	56.12	0.9883	2.08E-06	74.28	0.9946	4.90E-07
space	63.52	0.9855	6.91E-07	78.42	0.9888	5.25E-07
bash	70.60	0.9590	6.23E-06	88.16	0.9686	3.69E-06
v8	62.26	0.9811	4.03E-06	79.98	0.9896	1.60E-06

Experiment 2A



The average APSC values with the increasing iterations in GA with Ord and E-Ord for four subjects respectively

Experiment 2B

The average iterations and average final APSC with Ord and E-Ord.

Test Case	Ord			E-Ord		
	avg iters	avg APSC	variation	avg iters	avg APSC	variation
flex	24.93	0.9867	1.93E-06	101.08	0.9980	3.32E-08
space	26.29	0.9838	7.30E-07	167.78	0.9940	2.06E-07
bash	27.42	0.9553	7.10E-06	194.34	0.9836	1.34E-06
v8	25.98	0.9782	4.28E-06	130.64	0.9971	1.90E-07

Experiment 3A

The average iterations and average final APSC with PMX and E-Ord

Test Case	PMX			E-Ord		
	avg iters	avg APSC	variation	avg iters	avg APSC	variation
flex	157.04	0.9967	1.93E-06	101.08	0.9980	3.32E-08
space	187.93	0.9929	3.67E-06	167.78	0.9940	2.06E-07
bash	229.54	0.9801	7.10E-06	194.34	0.9836	1.34E-06
v8	226.88	0.9964	4.08E-06	130.64	0.9971	1.90E-07

GAs achieved very high APSC value , but the number of iterations for E-Ord is much fewer than that for PMX.

Contribution

- Apply epistatic theory to TCP.
- Two crossover operators are proposed based on epistasis.
- Proposed crossovers outperformed other crossovers we studied yet.

Future work

- Analyze the ETS systematically.
- Improve mutation with ETS.
- Multi-objective ETS.

Q & A

Thanks