# LIMITED VALIDITY STRUCTURES

# TRAVELING SALESPERSON PROBLEM (TSP)

- **Given a (symmetric) matrix of distances between N cities**
- **Salesperson is to visit each city once and only once**
- **Goal is to minimize total distance traveling**

# TRAVELING SALESPERSON PROBLEM (TSP)

- **A tour can be represented by a permutation**
- **The items in the chromosome are always the same.**
- **Fitness does not depend on contents of the chromosome. Instead, it depends on the order of the items in the chromosome.**

# NAÏVE CROSSOVER IN TSP

## PARENTS

| Tour | | | | | | | | | | |
|------|---|---|---|---|---|----|---|---|---|----|
| A | 9 | 8 | 4 | 5 | 6 | 7 | 1 | 3 | 1 | 10 |
| B | 8 | 7 | 1 | 2 | 3 | 10 | 9 | 5 | 4 | 6 |

## OFFSPRING (ONE CROSSOVER POINT BETWEEN 3 AND 4)

| Tour | | | | | | | | | | |
|------|---|---|---|---|---|----|---|---|---|----|
| C | 9 | 8 | 4 | 2 | 3 | 10 | 9 | 5 | 4 | 6 |
| D | 8 | 7 | 1 | 5 | 6 | 7 | 1 | 3 | 1 | 10 |

# NAÏVE CROSSOVER IN TSP — CONTINUED

- **Syntactic invalidity**

# POSSIBLE REMEDIES

- **Deletion**
- **Penalization**
- **Repair**

# PROBLEMS WITH TWO OF THESE POSSIBLE REMEDIES

• **The number of permutations is very much smaller than the possible strings**
$$L! << L^L$$

• **Therefore, almost everything is deleted or penalized**
  • Nothing left
  • When everything is penalized, then, in effect, nothing is penalized

# BUILDING BLOCKS FOR TSP

- **A sub-tour from a relatively fit individual is a candidate for a good building block**

# PARTIALLY MATCHED CROSSOVER (PMX) (GOLDBERG *GASOML*, CHAPTER 5)

## PARENTS

| Tour | | | | | | | | | | |
|------|---|---|---|---|---|---|---|---|---|----|
| A | 9 | 8 | 4 | 5 | 6 | 7 | 1 | 3 | 2 | 10 |
| B | 8 | 7 | 1 | 2 | 3 | 10 | 9 | 5 | 4 | 6 |

## STEP 1: PMX OFFSPRING (CROSSOVER POINTS BETWEEN 3-4 AND 6-7)

| Tour | | | | | | | | | | |
|------|---|---|---|---|---|---|---|---|---|----|
| C | | | | 2 | 3 | 10 | | | | |
| D | | | | 5 | 6 | 7 | | | | |

## STEP 2: PMX OFFSPRING (REPAIR 1ST OFFSPRING)

| Tour | | | | | | | | | | |
|------|---|---|---|---|---|---|---|---|---|----|
| C | 9 | 8 | 4 | 2 | 3 | 10 | 1 | <u>6</u> | <u>5</u> | <u>7</u> |
| D | | | | 5 | 6 | 7 | | | | |

## STEP 2: PMX OFFSPRING (REPAIR 2ND OFFSPRING)

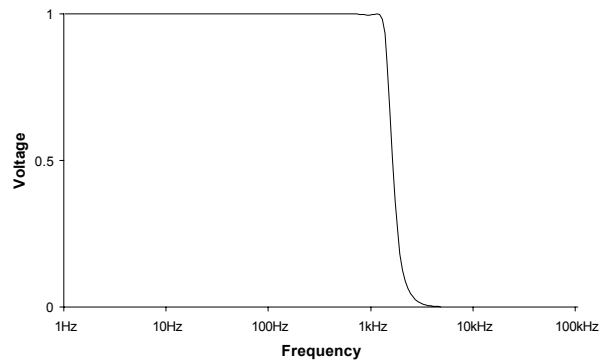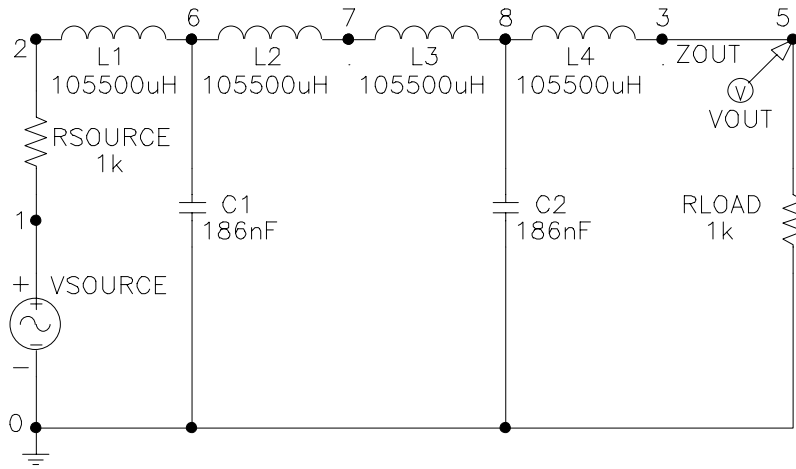| Tour | | | | | | | | | | |
|------|---|---|---|---|---|---|---|---|---|----|
| C | 9 | 8 | 4 | 2 | 3 | 10 | 1 | 6 | 5 | 7 |
| D | 8 | <u>10</u> | 1 | 5 | 6 | 7 | 9 | <u>2</u> | 4 | <u>5</u> |

# EVOLVED CAMPBELL FILTER
# CASCADE OF 6π SECTIONS
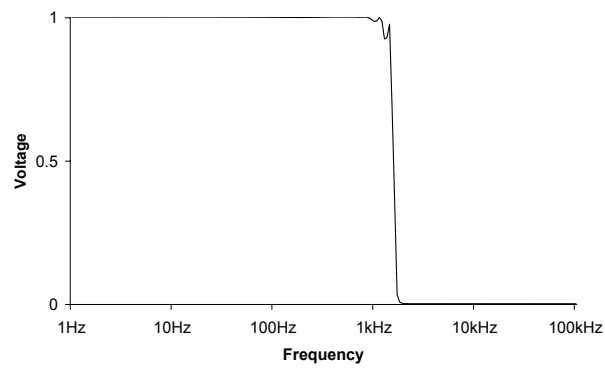# U. S. PATENT 1,227,113
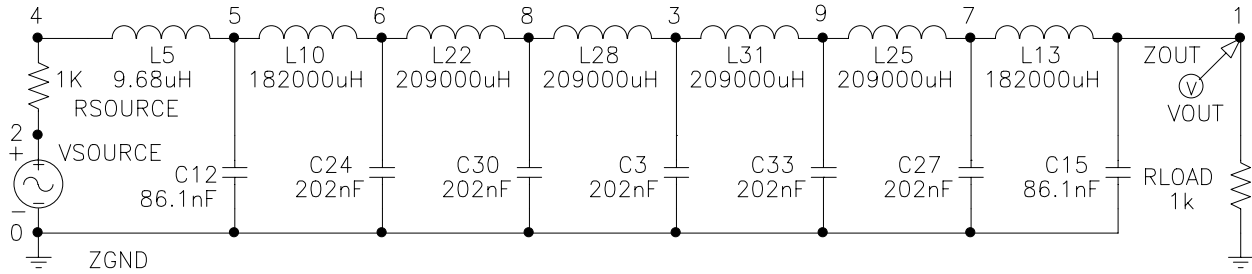
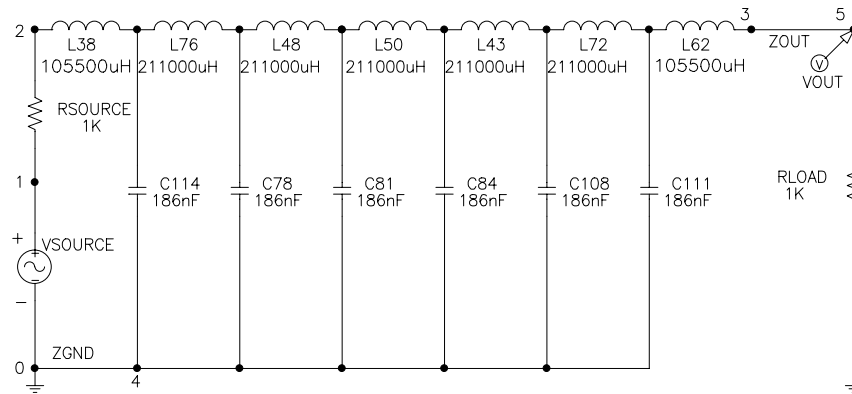# CIRCUIT CONSISTING OF ONE T-SECTION
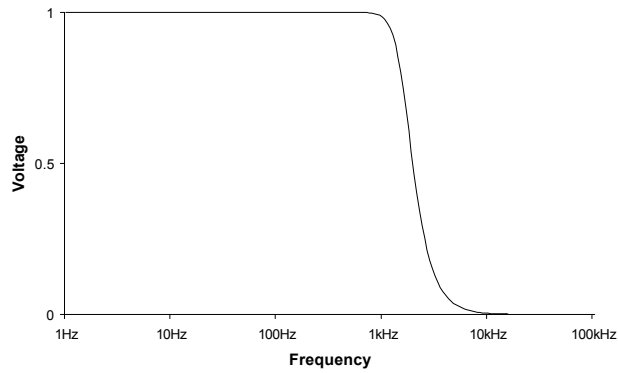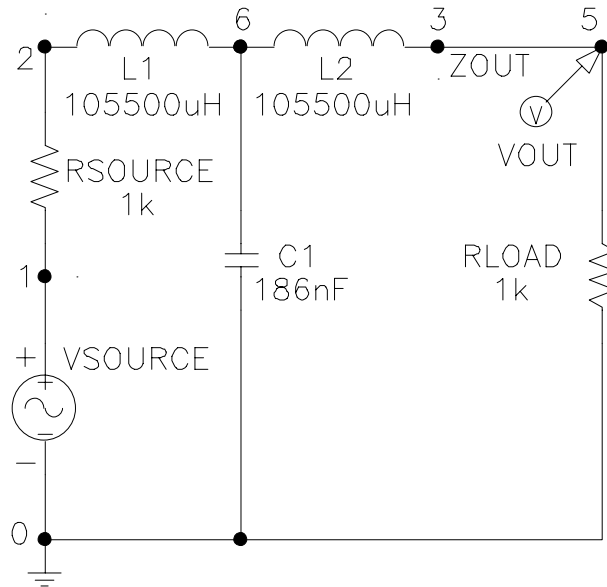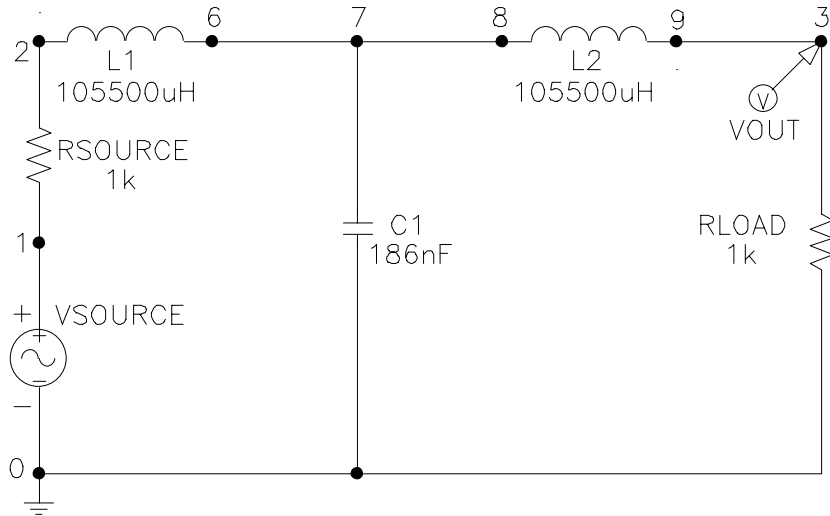
# CIRCUIT CONSISTING OF TWO T-SECTIONS

# CIRCUIT CONSISTING OF SIX T-SECTIONS
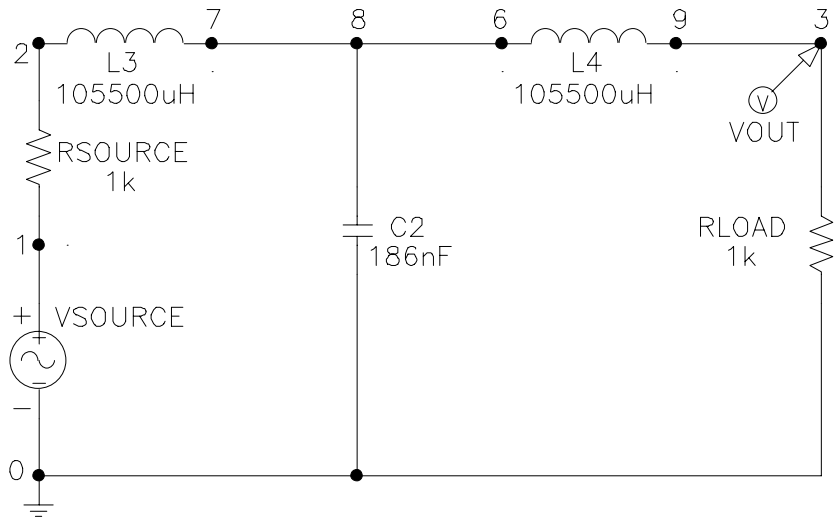
# ILLUSTRATIVE NAÏVE CROSSOVER

## FIRST PARENT



## GA CHROMOSOME OF 1ST PARENT

| L | 106 | 2 | 6 | W | 0 | 6 | 7 | C | 186 | 7 | 0 | W | 0 | 7 | 8 | L | 106 | 8 | 9 | W | 0 | 9 |
|---|-----|---|---|---|---|---|---|---|-----|---|---|---|---|---|---|---|-----|---|---|---|---|---|

The chromosome of the 1st parent codes for a single T-section that contains two inductors (**L1** and **L2**) and one capacitor (**C1**).

# ILLUSTRATIVE NAÏVE CROSSOVER

## SECOND PARENT



## GA CHROMOSOME OF 2$^{ND}$ PARENT

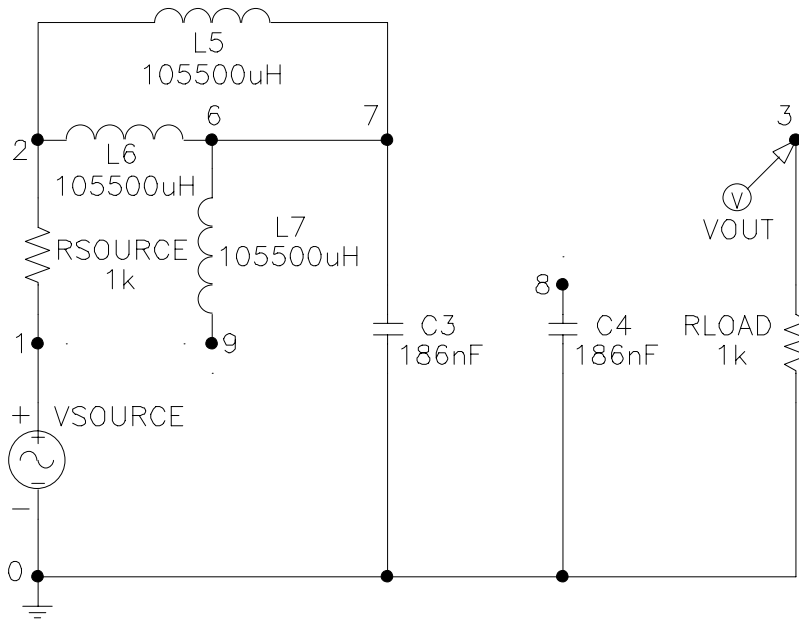| W | 0 | 8 | 6 | W | 0 | 9 | 3 | W | 0 | 7 | 8 | L | 106 | 6 | 9 | C | 186 | 8 | 0 | L | 106 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|-----|---|---|---|-----|---|---|---|-----|---|

**The chromosome of the 2$^{nd}$ parent codes for a single T-section that contains two inductors (L3 and L4) and one capacitor (C2). This individual is functionally equivalent to the first parent.**

# ILLUSTRATIVE NAÏVE CROSSOVER

# RESULT OF THE NAÏVE CROSSOVER (WITH THE CROSSOVER POINT AT THE RIGHT OF THE 12$^{TH}$ GENE)

# ONE OFFSPRING

| L | 105.5 | 2 | 6 | W | 0 | 6 | 7 | C | 186 | 7 | 0 | L | 106 | 6 | 9 | C | 186 | 8 | 0 | L | 106 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

# ILLUSTRATIVE CROSSOVER

# RESULT OF NAÏVE CROSSOVER — CONTINUED

- The offspring circuit contains three inductors and two capacitors.
- Components **L6** and **C3** originate from the $1^{st}$ parent (where they were called **L1** and **C1**, respectively).
- Components **L5, L7,** and **C4** originate from the $2^{nd}$ parent (where they were called **L3, L4,** and **C2** respectively).
- After the crossover, one end (node 9) of the inductor **L7** is left dangling.
- Similarly, one end (node 8) of the capacitor **C4** is also dangling.
- Moreover, the offspring has no connection to the output probe point **VOUT**.
- Because the offspring is syntactically invalid, a mechanism must now be invoked to repair it.

# NAÏVE CROSSOVER IN TSP — CONTINUED

- **Syntactic invalidity**

# POSSIBLE REMEDIES

- **Deletion**
- **Penalization**
- **Repair**

# THE PROBLEM WITH REPAIR

- **Repair usually amounts to mutation**

# CROSSOVER v. MUTATION

## COMPARISON OF CROSSOVER, MUTATION, AND BLIND RANDOM SEARCH

| | Remainder comes from a randomly chosen subtree of a | Fragment comes from a randomly chosen subtree of a |
|---|---|---|
| **Blind random search** | random parent from current generation 0. | random parent from current generation 0. |
| **Mutation** | fitness-selected parent from current generation $i$. | random parent from generation 0. |
| **Crossover** | fitness-selected parent from current generation $i$. | fitness-selected parent from current generation $i$. |

# SEARCH SPACE FOR THE HAMBURGER RESTAURANT PROBLEM
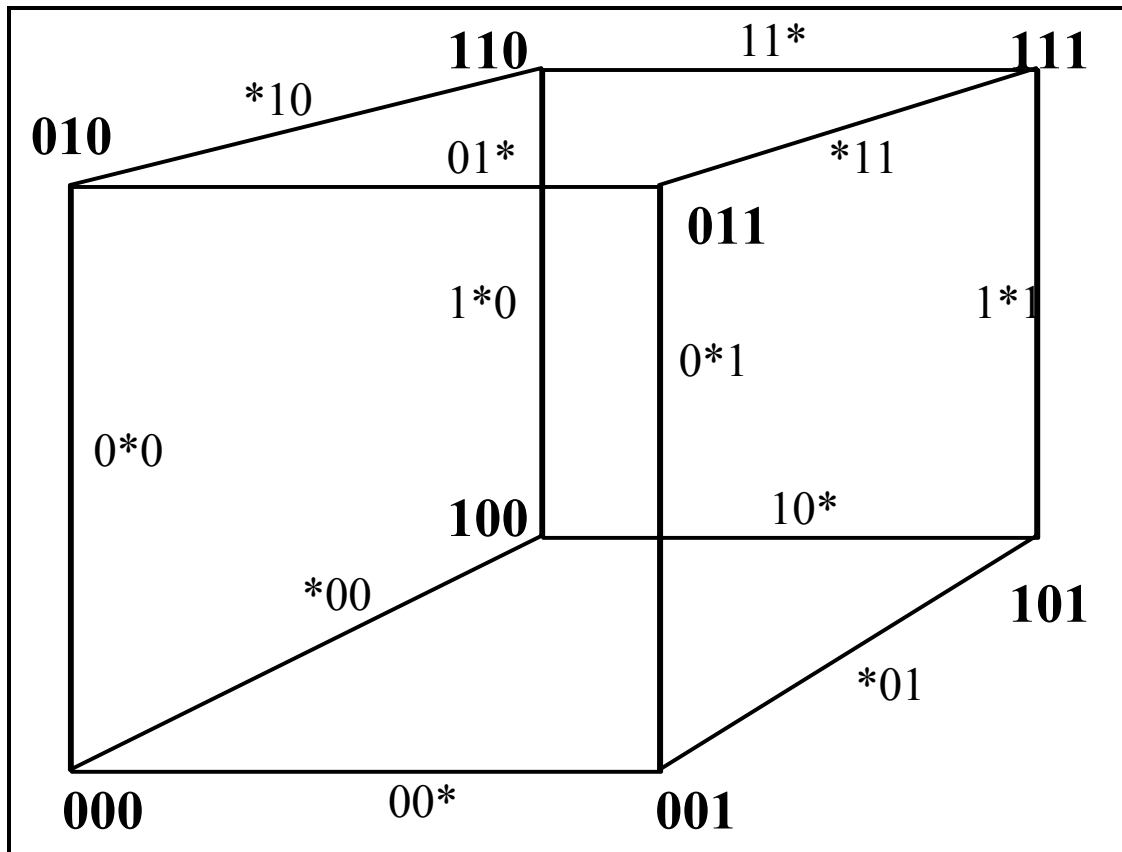
# GEOMETRIC INTERPRETATION OF THE MUTATION OPERATION

- **The single parent is 011**
- **The 3 possible offspring for a single mutation are 001, 010, or 111**
- **The 3 possible offspring are Hamming distance 1 from the parent**



110    **111**

**010**    **011**    Line ***11**

Line **01***

Line **0*1**

100    101

000    **001**
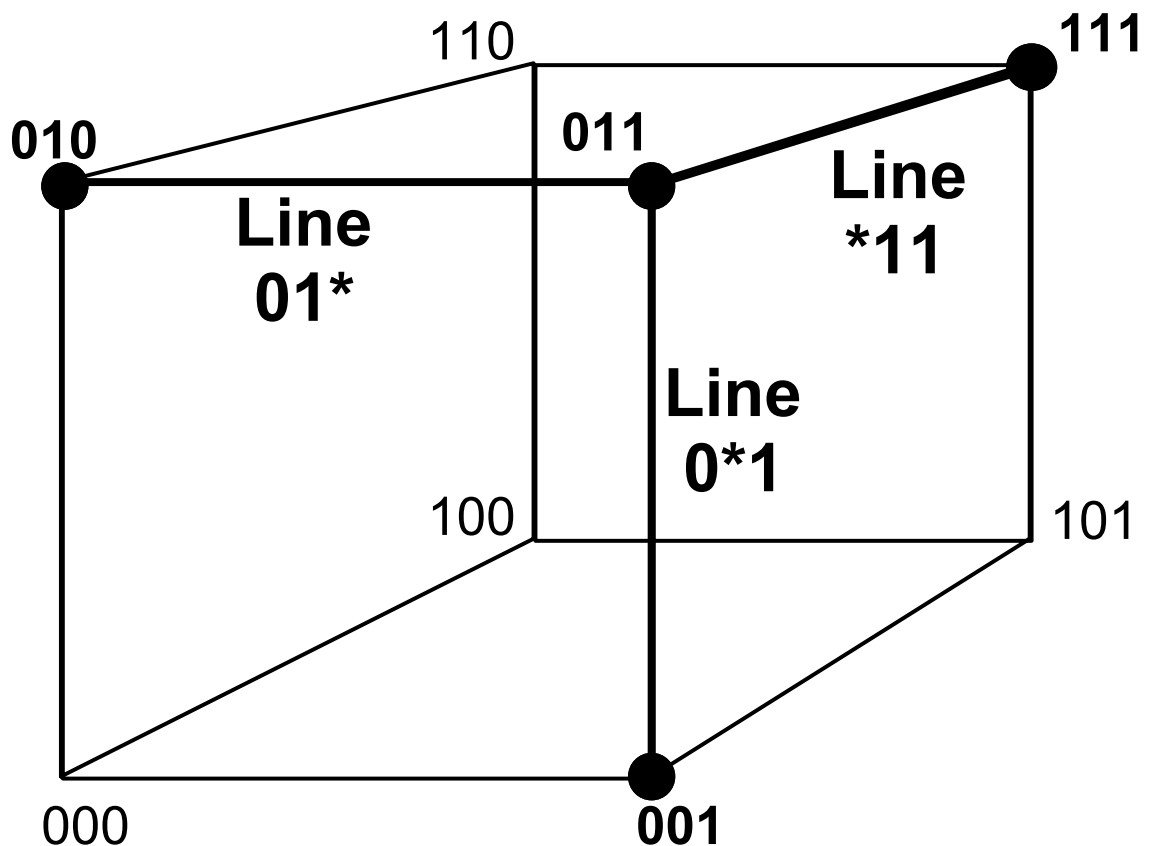
# GEOMETRIC INTERPRETATION OF THE CROSSOVER OPERATION

• **The parents are 110 and 011**

• **The crossover point is between $2^{nd}$ and $3^{rd}$ positions in the chromosome**

• **Offspring 111 lies at intersection of schema 11\* and \*\*1**