Data Structures and Algorithms in Java

Procedural Programming: Arrays

Outline

One Dimensional (1D) Arrays

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An array is an ordered collection of values

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```
<type>[] <name> = {<expression>, <expression>, ...};

<type>[] <name>;
<name> = new <type>[] {<expression>, <expression>, ...};
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```

Example

```
String[] suits = {"Clubs", "Diamonds", "Hearts", "Spades"};

double[] powersOfTwo;
powersOfTwo = new double[] {0.125, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0};
```

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Example

```
int[] x = new int[10];

boolean[] y;
y = new boolean[20]
```

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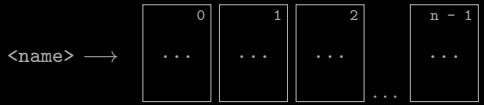

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The `i`th element in an array `x` is accessed as `x[i]`, where `0 <= i < n`

The `i`th element in an array `x` is assigned a value as

```
x[i] = <expression>;
```

One Dimensional (1D) Arrays

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Example (Identity Permutation)

```
1  int[] perm;
2
3  perm = new int[5];
4
5  for (int i = 0; i < 5; i++) {
6      perm[i] = i;
7  }
```

line #	perm	i

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Example (In-place Reversal)

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4      int temp = perm[i];
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3  for (int i = 0; i < 5; i++) {
4      int r = StdRandom.uniform(i, 5);
5      int temp = perm[r];
6      perm[r] = perm[i];
7      perm[i] = temp;
8  }
```

line #	perm	i	r
3	3,2,1,4,0	5	

One Dimensional (1D) Arrays

Example (Knuth Shuffle)

```
1  int[] perm = {0, 1, 2, 3, 4};
2
3  for (int i = 0; i < 5; i++) {
4      int r = StdRandom.uniform(i, 5);
5      int temp = perm[r];
6      perm[r] = perm[i];
7      perm[i] = temp;
8  }
```

line #	perm	i	r

One Dimensional (1D) Arrays

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`Sample.java`

- Command-line input: m (int) and n (int)
- Standard output: a random sample (without replacement) of m integers, each from the interval $[0, n)$

One Dimensional (1D) Arrays

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```
× ~/workspace/dsaj
$ _
```

One Dimensional (1D) Arrays

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- Command-line input: m (int) and n (int)
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~/workspace/dsaj

```
$ java Sample 6 16
```

One Dimensional (1D) Arrays

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× ~/workspace/dsaj

```
$ java Sample 6 16
11 10 12 13 6 8
$ _
```

One Dimensional (1D) Arrays

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```
$ java Sample 6 16
11 10 12 13 6 8
$ java Sample 10 1000
```

One Dimensional (1D) Arrays

`Sample.java`

- Command-line input: m (int) and n (int)
- Standard output: a random sample (without replacement) of m integers, each from the interval $[0, n)$

```
× ~/workspace/dsaj
$ java Sample 6 16
11 10 12 13 6 8
$ java Sample 10 1000
21 432 270 287 166 484 437 675 78 213
$ _
```

One Dimensional (1D) Arrays

`Sample.java`

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- Standard output: a random sample (without replacement) of m integers, each from the interval $[0, n)$

× ~/workspace/dsaj

```
$ java Sample 6 16
11 10 12 13 6 8
$ java Sample 10 1000
21 432 270 287 166 484 437 675 78 213
$ java Sample 20 20
```

One Dimensional (1D) Arrays

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- Command-line input: m (int) and n (int)
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× ~/workspace/dsaj

```
$ java Sample 6 16
11 10 12 13 6 8
$ java Sample 10 1000
21 432 270 287 166 484 437 675 78 213
$ java Sample 20 20
9 0 15 13 4 8 11 17 3 18 16 5 7 19 14 12 2 1 10 6
$ _
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9
perm[i]	0	0	0	0	0	0	0	0	0	0

m = 5, n = 10

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9
perm[i]	0	1	2	3	4	5	6	7	8	9

m = 5, n = 10

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9
perm[i]	3	7	2	9	1	5	6	4	8	0

m = 5, n = 10

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

× Sample.java 1/2

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class Sample {
    public static void main(String[] args) {
        int m = Integer.parseInt(args[0]);
        int n = Integer.parseInt(args[1]);
        int[] perm = new int[n];
        for (int i = 0; i < n; i++) {
            perm[i] = i;
        }
        for (int i = 0; i < m; i++) {
            int r = StdRandom.uniform(i, n);
            int temp = perm[r];
            perm[r] = perm[i];
            perm[i] = temp;
        }
        for (int i = 0; i < m; i++) {
            StdOut.print(perm[i] + " ");
        }
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

× Sample.java 2/2

```
21          StdOut.println();
22      }
23  }
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

One Dimensional (1D) Arrays

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```
× ~/workspace/dsaj
$ _
```

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/dsaj
$ java CouponCollector 1000
```

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/dsaj
$ java CouponCollector 1000
8317
$ _
```

One Dimensional (1D) Arrays

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- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
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8317
$ java CouponCollector 1000
```

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/dsaj
$ java CouponCollector 1000
8317
$ java CouponCollector 1000
7867
$ _
```

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/dsaj
$ java CouponCollector 1000
8317
$ java CouponCollector 1000
7867
$ java CouponCollector 1000000


```

One Dimensional (1D) Arrays

`CouponCollector.java`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/dsaj
$ java CouponCollector 1000
8317
$ java CouponCollector 1000
7867
$ java CouponCollector 1000000
15942756
$ _
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

value	count	collectedCount
	0	0

value	0	1	2
isCollected[value]	F	F	F

One Dimensional (1D) Arrays

value	count	collectedCount
1	1	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Arrays

value	count	collectedCount
1	2	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Arrays

value	count	collectedCount
1	3	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Arrays

value	count	collectedCount
2	4	2

value	0	1	2
isCollected[value]	F	T	T

One Dimensional (1D) Arrays

value	count	collectedCount
0	5	3

value	0	1	2
isCollected[value]	T	T	T

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

× CouponCollector.java

```java
import stdlib.StdOut;
import stdlib.StdRandom;

public class CouponCollector {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int count = 0;
        int collectedCount = 0;
        boolean[] isCollected = new boolean[n];
        while (collectedCount < n) {
            int value = StdRandom.uniform(0, n);
            count++;
            if (!isCollected[value]) {
                collectedCount++;
                isCollected[value] = true;
            }
        }
        StdOut.println(count);
    }
}
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

One Dimensional (1D) Arrays

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- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ _
```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
4
$ _
```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
4
$ java PrimeSieve 100
```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
4
$ java PrimeSieve 100
25
$ _
```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
4
$ java PrimeSieve 100
25
$ java PrimeSieve 1000


```

One Dimensional (1D) Arrays

`PrimeSieve.java`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/dsaj
$ java PrimeSieve 10
4
$ java PrimeSieve 100
25
$ java PrimeSieve 1000
168
$ _
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	F	F	F	F	F	F	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	T	T	T	T	T	T	T

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	T	T	T	T	T	T	T

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	T	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	T	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

× PrimeSieve.java 1/2

```java
import stdlib.StdOut;

public class PrimeSieve {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        boolean[] isPrime = new boolean[n + 1];
        for (int i = 2; i <= n; i++) {
            isPrime[i] = true;
        }
        for (int i = 2; i < n; i++) {
            if (isPrime[i]) {
                for (int j = 2; j <= n / i; j++) {
                    isPrime[i * j] = false;
                }
            }
        }
        int count = 0;
        for (int i = 2; i <= n; i++) {
            count += isPrime[i] ? 1 : 0;
        }
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

× PrimeSieve.java 2/2

```
21          StdOut.println(count);
22      }
23  }
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

Aliasing refers to the situation where two variables refer to the same object

One Dimensional (1D) Arrays

Aliasing refers to the situation where two variables refer to the same object

Example

```
int[] x = {1, 3, 7};
int[] y = x;
x[1] = 42;

StdOut.println(x[1]);
StdOut.println(y[1]);
```

writes

```
42
42
```

One Dimensional (1D) Arrays

One Dimensional (1D) Arrays

Example (creating a copy of an array x of ints)

```
int[] y = new int[x.length];

for (int i = 0; i < x.length; i++) {
    y[i] = x[i];
}
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

```
<type>[][] <name> = {{<expression>, <expression>, ...},
                     {<expression>, <expression>, ...},
                     ...
                     {<expression>, <expression>, ...}};

<type>[][] <name>;
<name> = new <type>[][] {{<expression>, <expression>, ...},
                         {<expression>, <expression>, ...},
                         ...
                         {<expression>, <expression>, ...}};
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

Example

```
int[][] identity = {{1, 0, 0},
                    {0, 1, 0},
                    {0, 0, 1}};

int[][] pascal;

pascal = new int[][] {{1, 0, 0, 0, 0},
                      {1, 1, 0, 0, 0},
                      {1, 2, 1, 0, 0},
                      {1, 3, 3, 1, 0},
                      {1, 4, 6, 4, 1}};
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

```
<type>[][] <name> = new <type>[<nrows>][<ncols>];

<type>[][] <name>;
<name> = new <type>[<nrows>][<ncols>];
```

Two Dimensional (2D) Arrays

```
<type>[][] <name> = new <type>[<nrows>][<ncols>];

<type>[][] <name>;
<name> = new <type>[<nrows>][<ncols>];
```

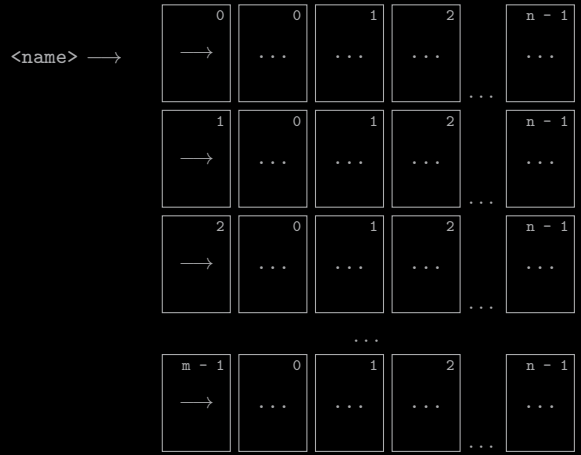
Example

```
double[][] x = new double[10][10];

int[][] y;
y = new int[5][10];
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays



Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

The number of rows (say `m`) in an array `x` is obtained as `x.length`

Two Dimensional (2D) Arrays

The number of rows (say `m`) in an array `x` is obtained as `x.length`

The number of columns (say `n`) in an array `x` is obtained as `x[0].length`

Two Dimensional (2D) Arrays

- The number of rows (say `m`) in an array `x` is obtained as `x.length`
- The number of columns (say `n`) in an array `x` is obtained as `x[0].length`
- The element in row `i` and column `j` of an array `x` is accessed as `x[i][j]`, where `0 <= i < m` and `0 <= j < n`

Two Dimensional (2D) Arrays

The number of rows (say `m`) in an array `x` is obtained as `x.length`

The number of columns (say `n`) in an array `x` is obtained as `x[0].length`

The element in row `i` and column `j` of an array `x` is accessed as `x[i][j]`, where `0 <= i < m` and `0 <= j < n`

The element in row `i` and column `j` of an array `x` is assigned a value as

```
x[i][j] = <expression>;
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
1			

Two Dimensional (2D) Arrays

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```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
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4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
2			

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
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5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
4	0,0|0,0		

Two Dimensional (2D) Arrays

Example (Matrix Addition)

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1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
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6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
5	0,0|0,0	0	

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
6	0,0|0,0	0	0

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
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5  for (int i = 0; i < 2; i++) {
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7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
7	3,0|0,0	0	0

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
6	3,0|0,0	0	1

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
7	3,5|0,0	0	1

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
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5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
6	3,5|0,0	0	

Two Dimensional (2D) Arrays

Example (Matrix Addition)

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8      }
9  }
```

line #	c	i	j
5	3,5|0,0	1	

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
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8      }
9  }
```

line #	c	i	j
6	3,5|0,0	1	0

Two Dimensional (2D) Arrays

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5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
8      }
9  }
```

line #	c	i	j
7	3,5|7,0	1	0

Two Dimensional (2D) Arrays

Example (Matrix Addition)

```
1  int[][] a = {{1, 2}, {3, 4}};
2  int[][] b = {{2, 3}, {4, 5}};
3
4  int[][] c = {{0, 0}, {0, 0}};
5  for (int i = 0; i < 2; i++) {
6      for (int j = 0; j < 2; j++) {
7          c[i][j] = a[i][j] + b[i][j];
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9  }
```

line #	c	i	j
6	3,5|7,0	1	1

Two Dimensional (2D) Arrays

Example (Matrix Addition)

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Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

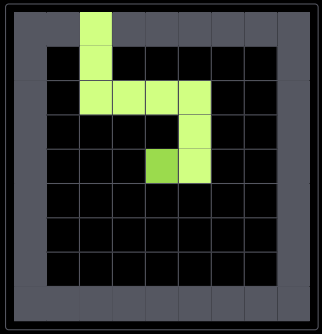
`SelfAvoid.java`

- Command-line input: n (int) and *trials* (int)
- Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

Two Dimensional (2D) Arrays

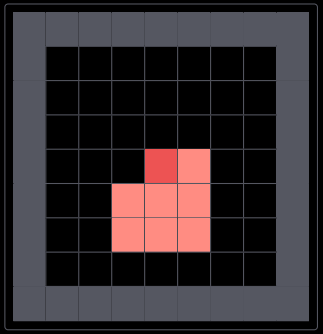
Two Dimensional (2D) Arrays

Escape



→ ↑ ↑ ← ← ← ↑ ↑

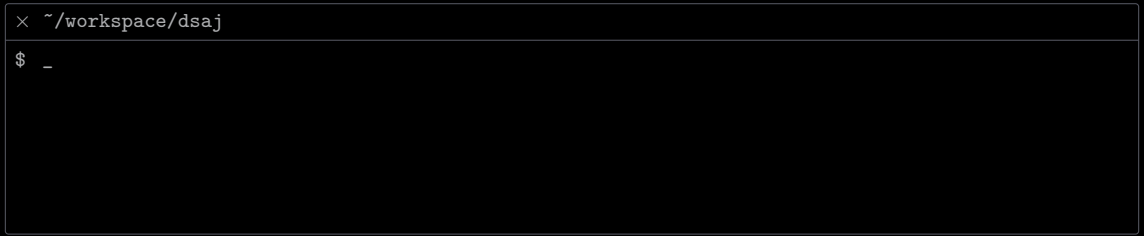
Dead End



→ ↓ ↓ ← ← ↑ →

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays



Two Dimensional (2D) Arrays

~/workspace/dsaj

```
$ java SelfAvoid 20 1000
```

Two Dimensional (2D) Arrays

```
× ~/workspace/dsaj
$ java SelfAvoid 20 1000
32% dead ends
$ _
```

Two Dimensional (2D) Arrays

× ~/workspace/dsaj

```
$ java SelfAvoid 20 1000
32% dead ends
$ java SelfAvoid 40 1000
```

Two Dimensional (2D) Arrays

```
× ~/workspace/dsaj
$ java SelfAvoid 20 1000
32% dead ends
$ java SelfAvoid 40 1000
75% dead ends
$ _
```

Two Dimensional (2D) Arrays

× ~/workspace/dsaj

```
$ java SelfAvoid 20 1000
32% dead ends
$ java SelfAvoid 40 1000
75% dead ends
$ java SelfAvoid 80 1000


```

Two Dimensional (2D) Arrays

```
× ~/workspace/dsaj
$ java SelfAvoid 20 1000
32% dead ends
$ java SelfAvoid 40 1000
75% dead ends
$ java SelfAvoid 80 1000
98% dead ends
$ _
```

Two Dimensional (2D) Arrays

Two Dimensional (2D) Arrays

× SelfAvoid.java 1/2

```
import stdlib.StdOut;
import stdlib.StdRandom;

public class SelfAvoid {
    public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        int trials = Integer.parseInt(args[1]);
        int deadEnds = 0;
        for (int t = 0; t < trials; t++) {
            boolean[][] a = new boolean[n][n];
            int x = n / 2;
            int y = n / 2;
            while (x > 0 && x < n - 1 && y > 0 && y < n - 1) {
                a[x][y] = true;
                if (a[x - 1][y] && a[x + 1][y] && a[x][y - 1] && a[x][y + 1]) {
                    deadEnds++;
                    break;
                }
                int r = StdRandom.uniform(1, 5);
                if (r == 1 && !a[x + 1][y]) {
```

Two Dimensional (2D) Arrays

× SelfAvoid.java 2/2

```
21                      x++;
22                  } else if (r == 2 && !a[x - 1][y]) {
23                      x--;
24                  } else if (r == 3 && !a[x][y + 1]) {
25                      y++;
26                  } else if (r == 4 && !a[x][y - 1]) {
27                      y--;
28                  }
29              }
30          }
31          StdOut.println(100 * deadEnds / trials + "% dead ends");
32      }
33  }
```

Converting 2D Arrays to 1D Arrays and Vice Versa

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Converting an $m \times n$ array X into a 1D array Y

- The element $X(i, j)$ maps to the element $Y(k)$, where $k = n \cdot i + j$

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Example

$$X = \begin{array}{c} \begin{array}{ccccc} 0 & 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} A & B & C & D & E \\ F & G & H & I & J \\ K & L & M & N & O \end{bmatrix} \end{array} \begin{array}{c} 0 \\ 1 \\ 2 \end{array}$$

$$Y = \begin{array}{c} \begin{array}{ccccccccccccccc} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 \end{array} \\ [A \quad B \quad C \quad D \quad E \quad F \quad G \quad H \quad I \quad J \quad K \quad L \quad M \quad N \quad O\,] \end{array}$$

Ragged Arrays

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A ragged array is a 2D array in which the rows have unequal number of columns

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The number of columns in the `i`th row of a ragged array `x` is obtained as `x[i].length`

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A ragged array is a 2D array in which the rows have unequal number of columns

The number of columns in the ith row of a ragged array x is obtained as `x[i].length`

Example (printing a ragged array)

```
int[][] pascal = {{1}, {1, 1}, {1, 2, 1}, {1, 3, 3, 1}, {1, 4, 6, 4, 1}};

for (int i = 0; i < pascal.length; i++) {
    for (int j = 0; j < pascal[i].length; j++) {
        StdOut.print(pascal[i][j] + " ");
    }
    StdOut.println();
}
```

writes

```
1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
```