Curtin University

LECTURE 4: GRAPHS (PART 2)

Software Engineering Testing (CMPE3008/CMPE4001/CMPE5000)

Created by Arlen Brower

OUTCOMES

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- Create control flow graphs from source code
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- Identify test paths for the above

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- Used to formally define a means to tackle loops.

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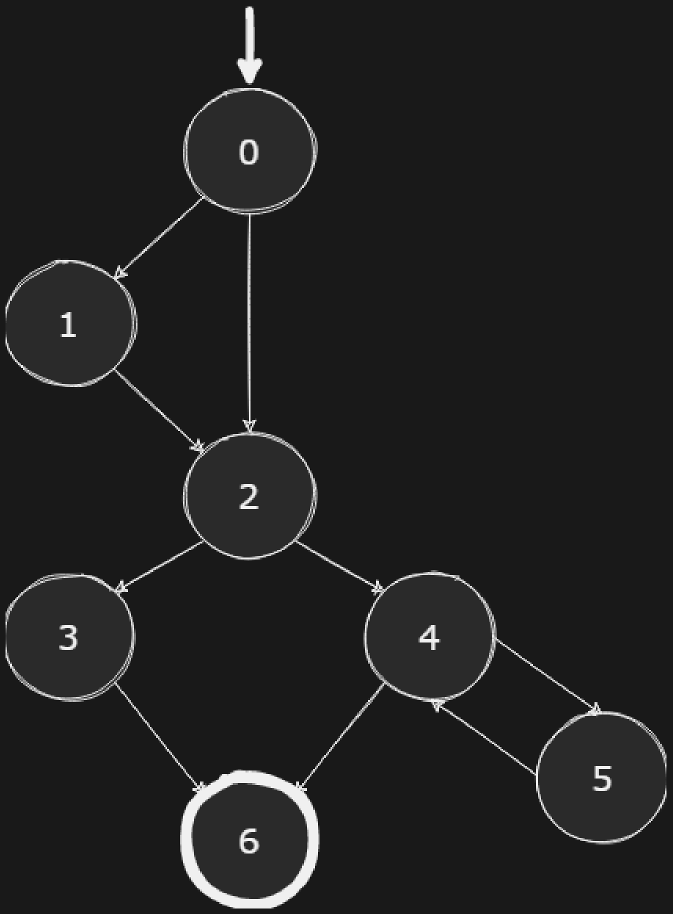

What are the prime paths?

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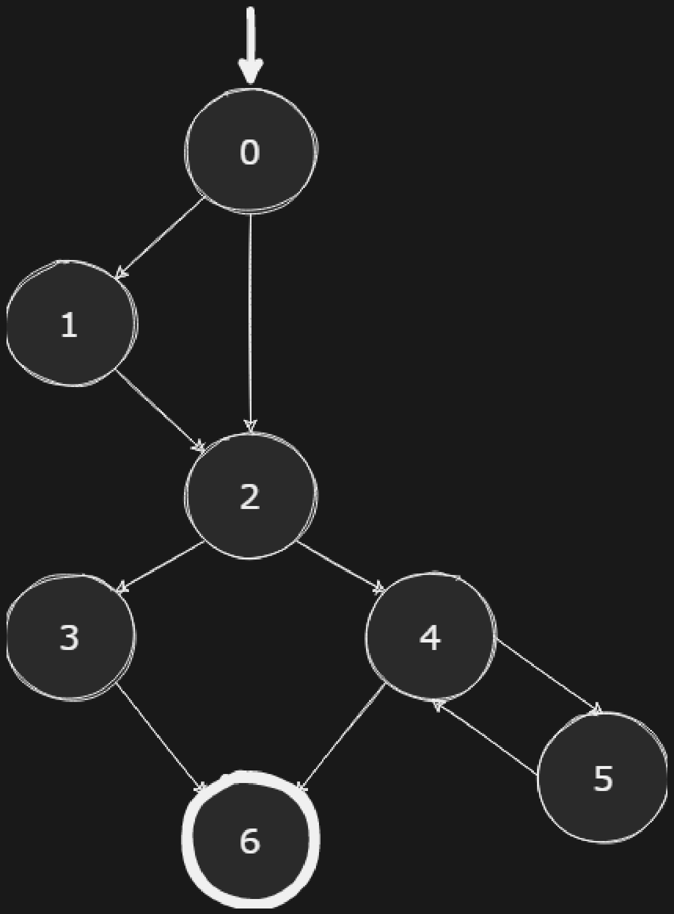

What are the prime paths?

There are nine...

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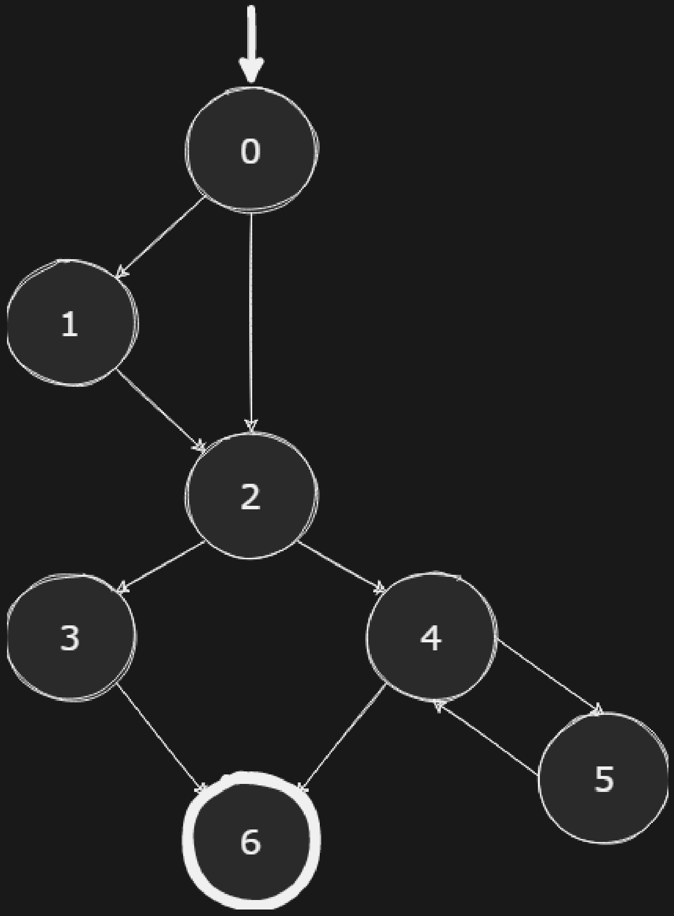

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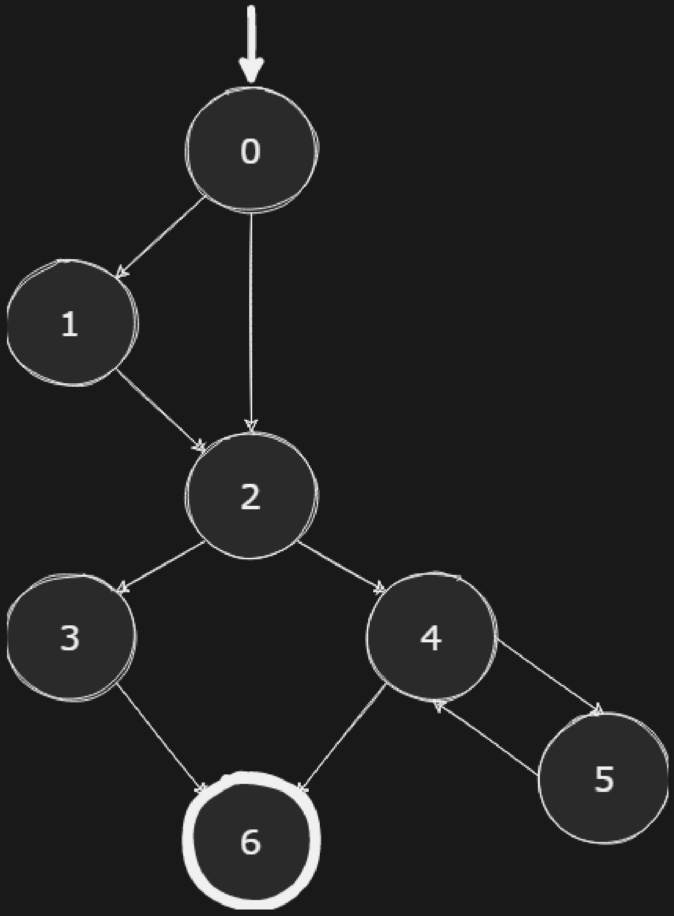

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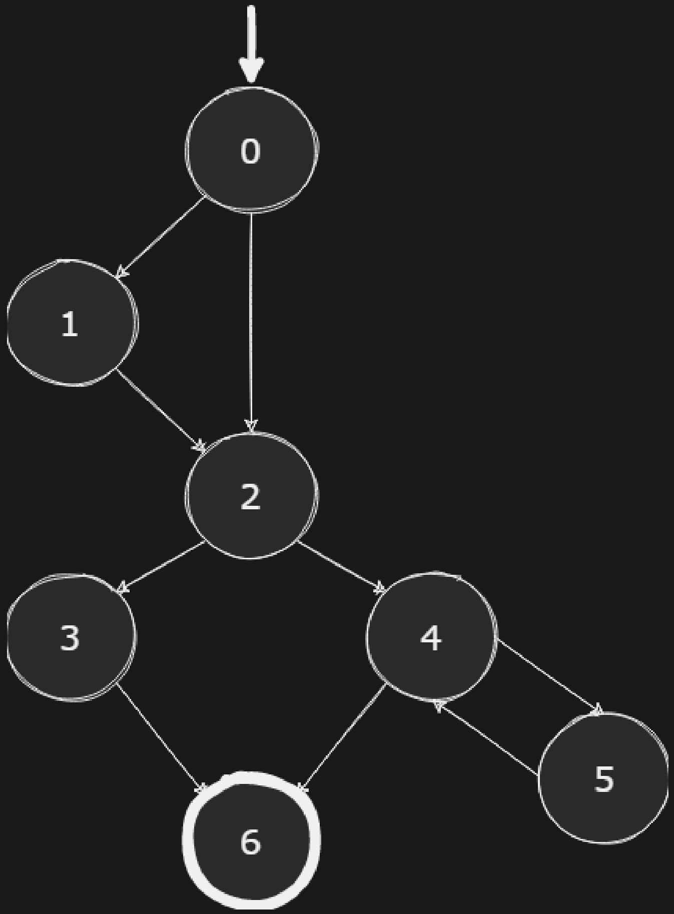

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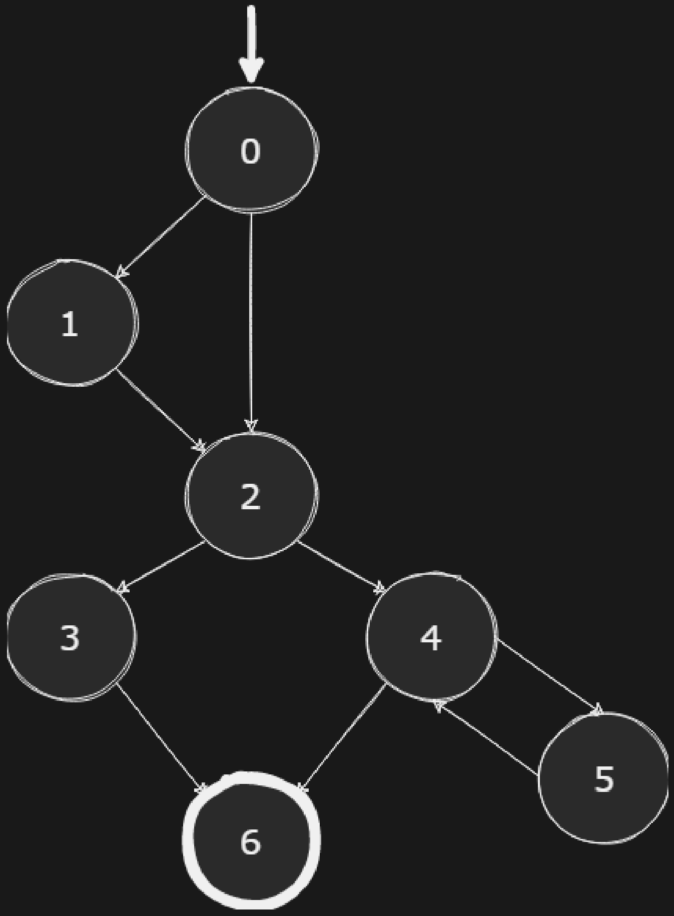

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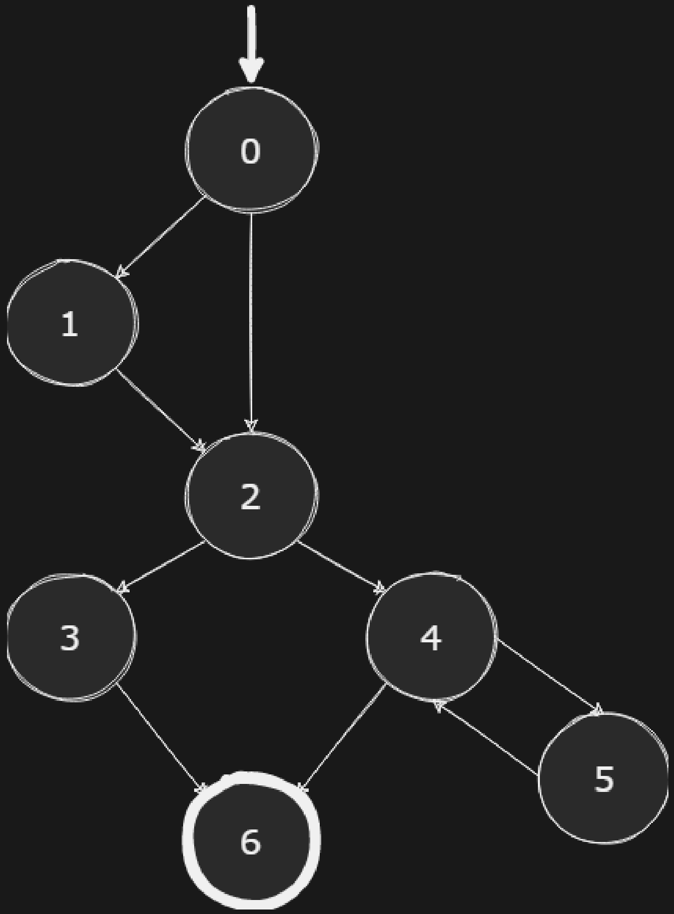

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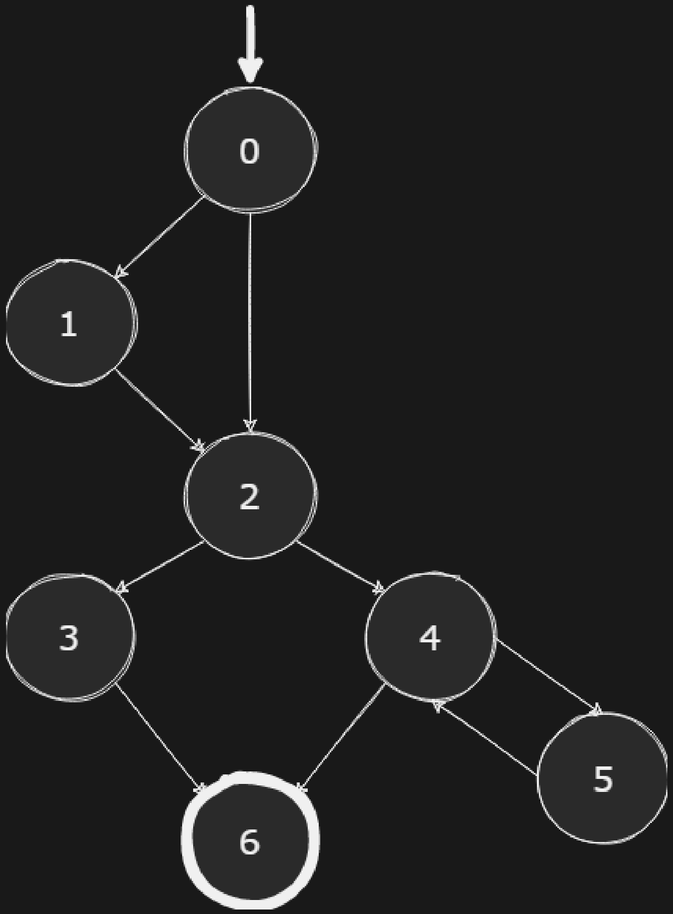

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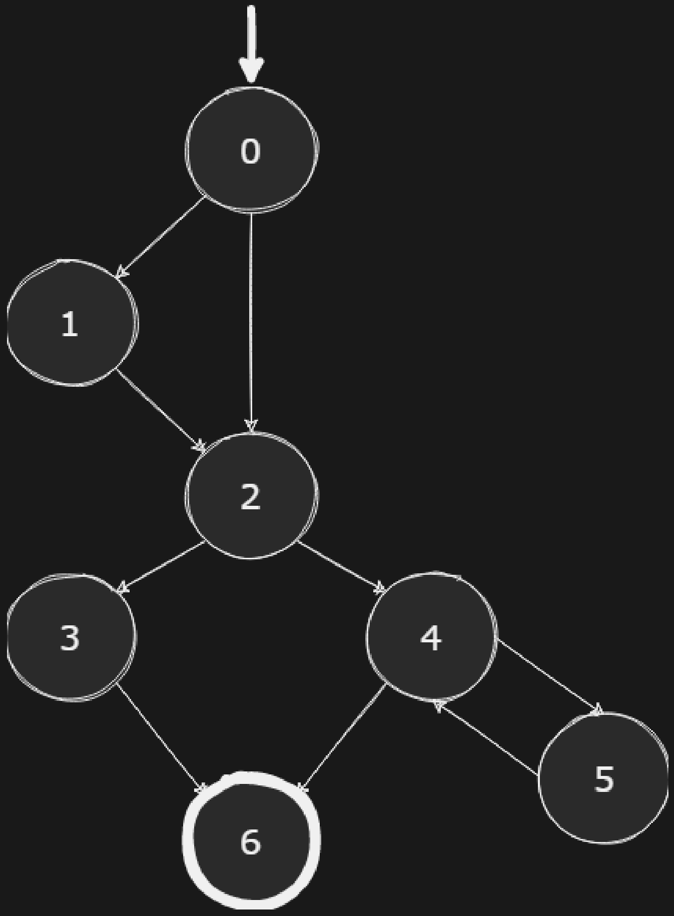

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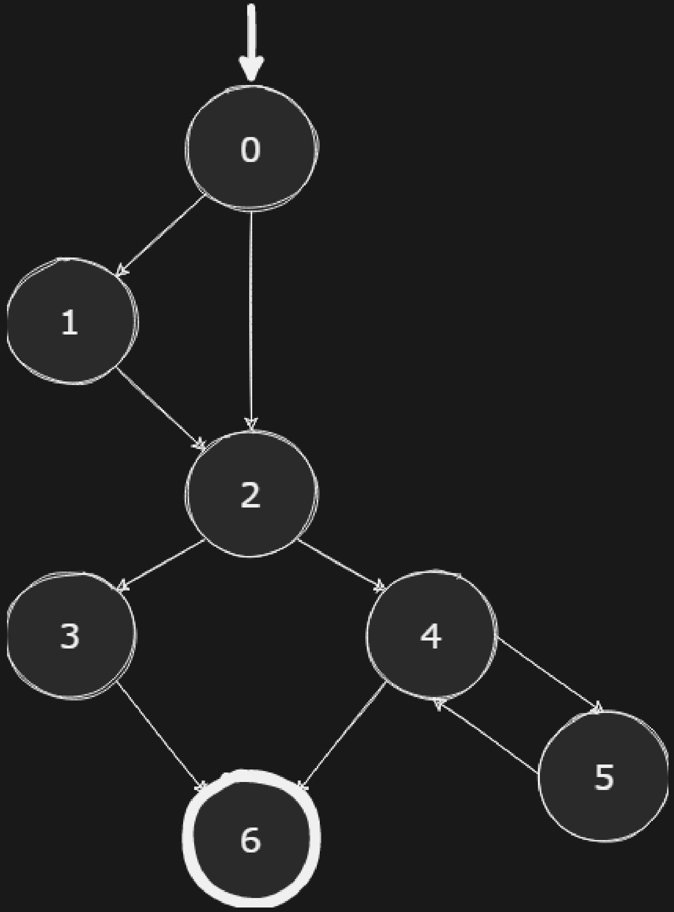

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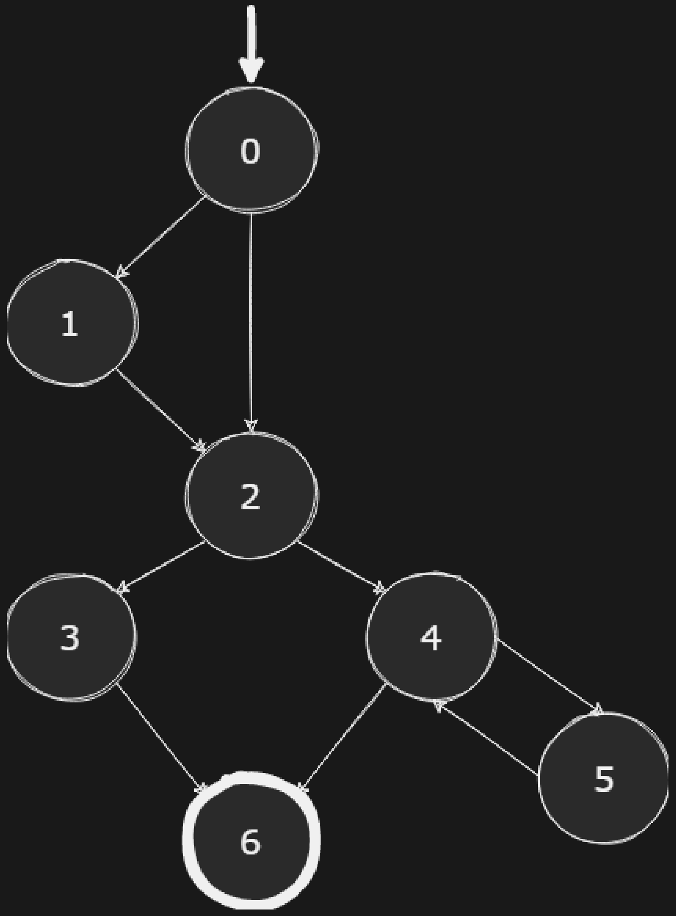

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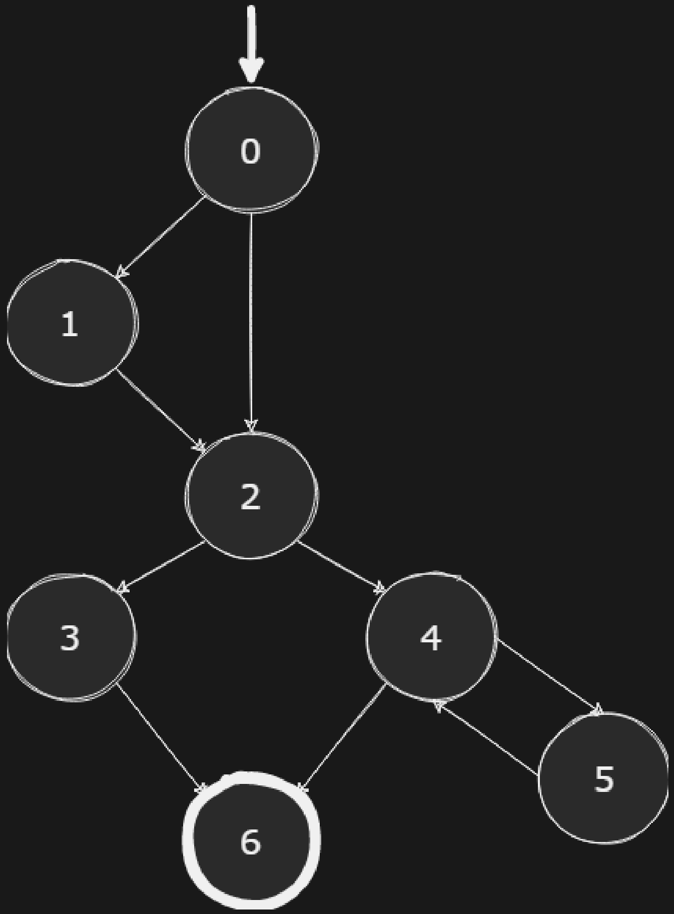

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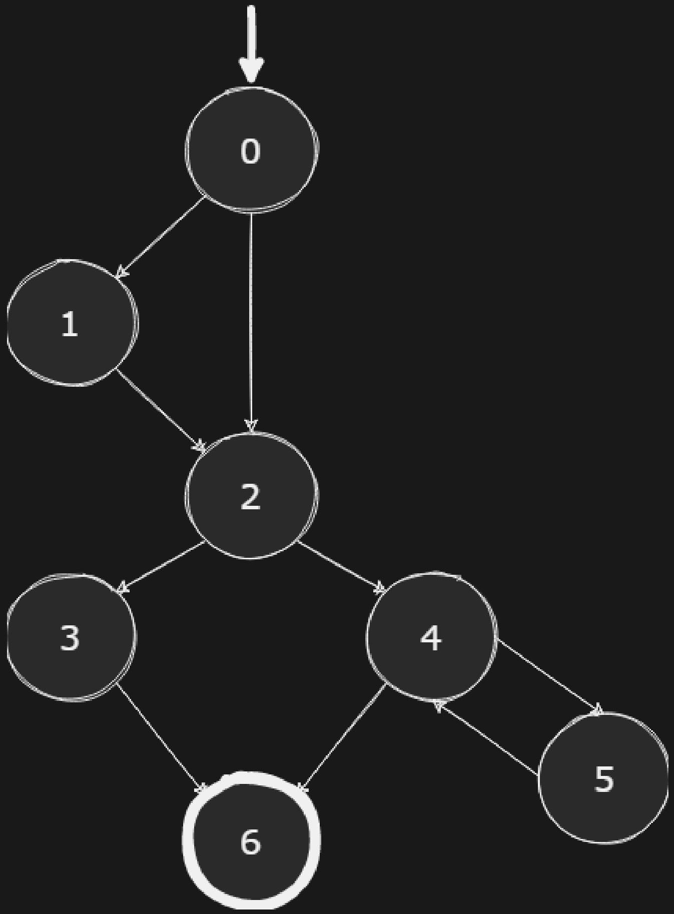

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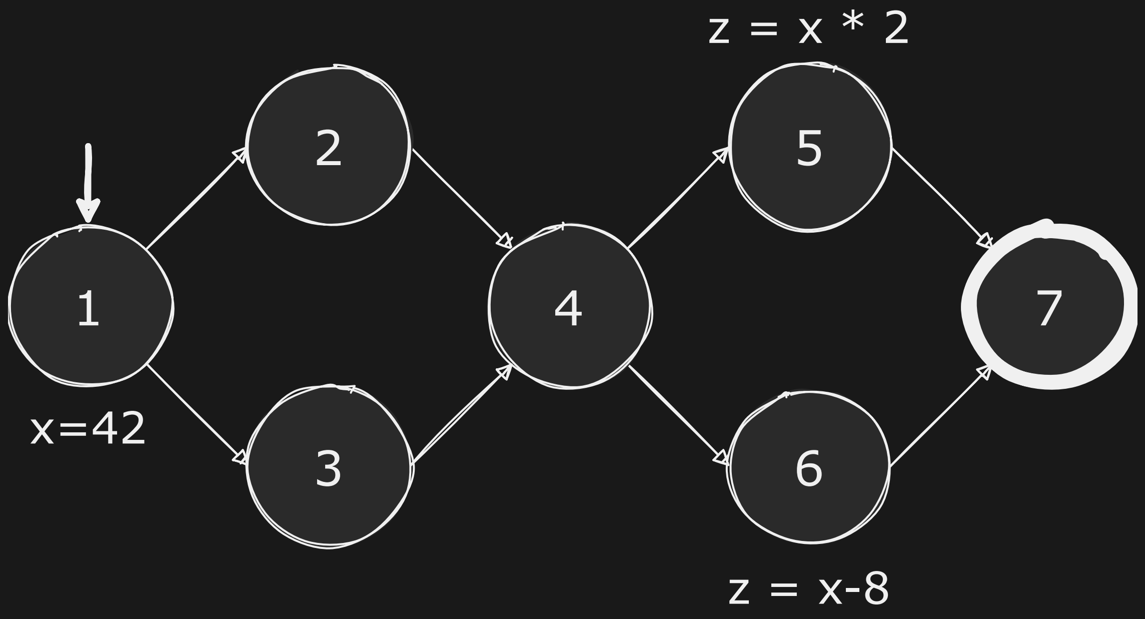

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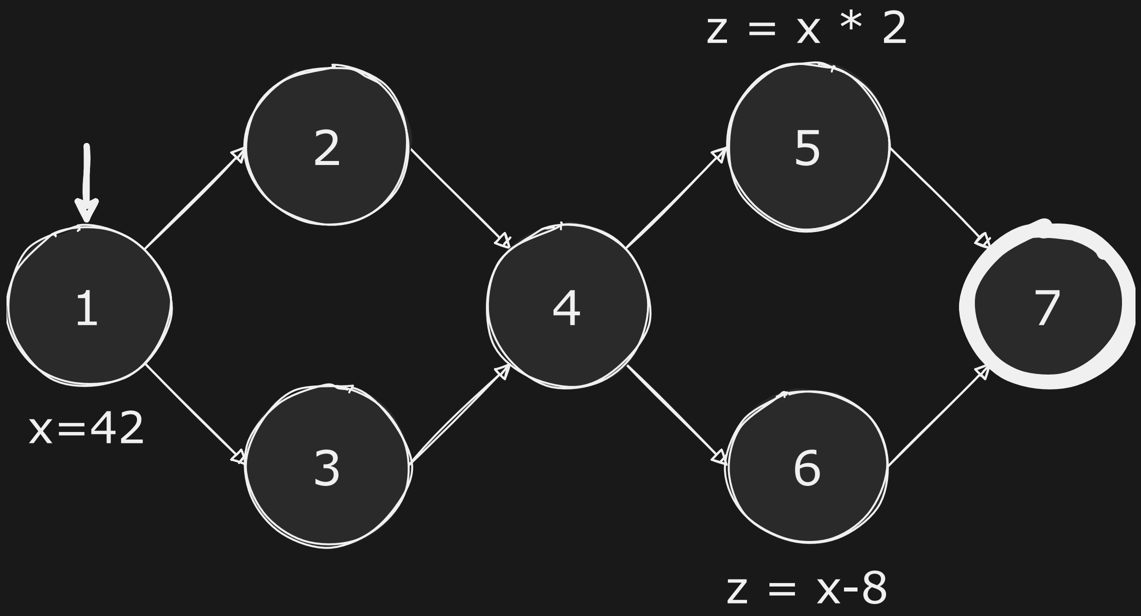

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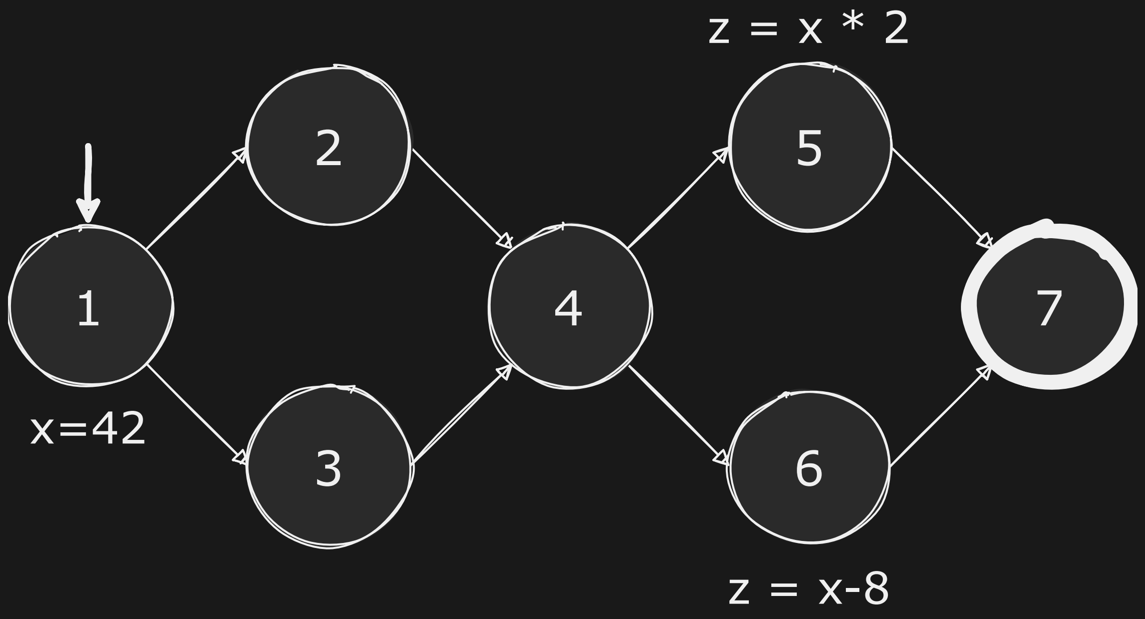

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Prepare for more terminology!

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- du-path: A *simple* subpath that is def-clear with respect to a DU pair

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- $$du(n_i, v)$$

  The set of du-paths that start at one location

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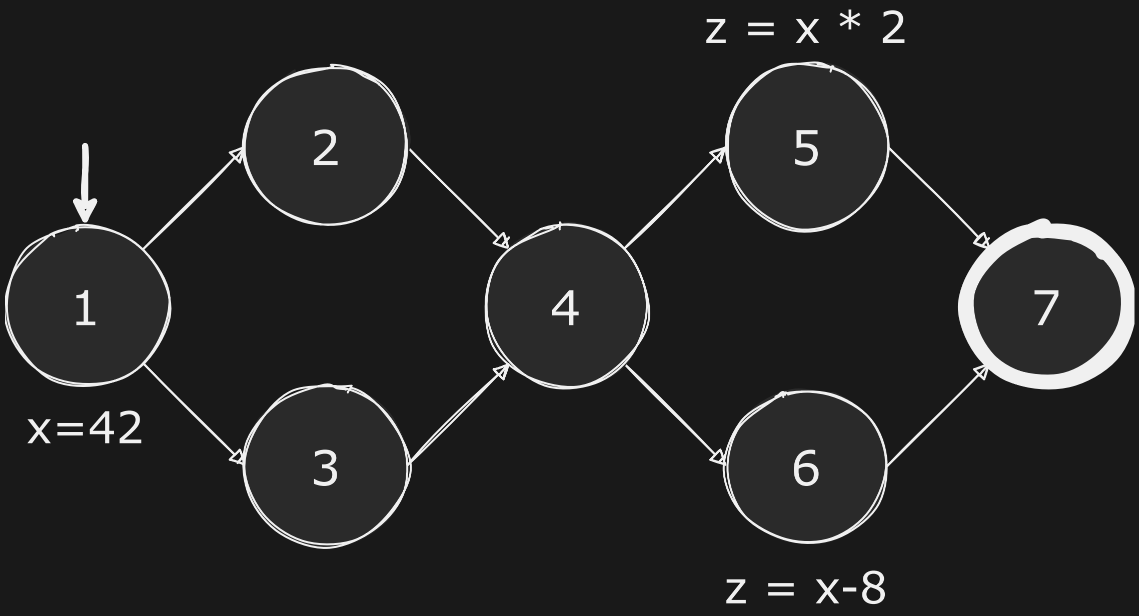
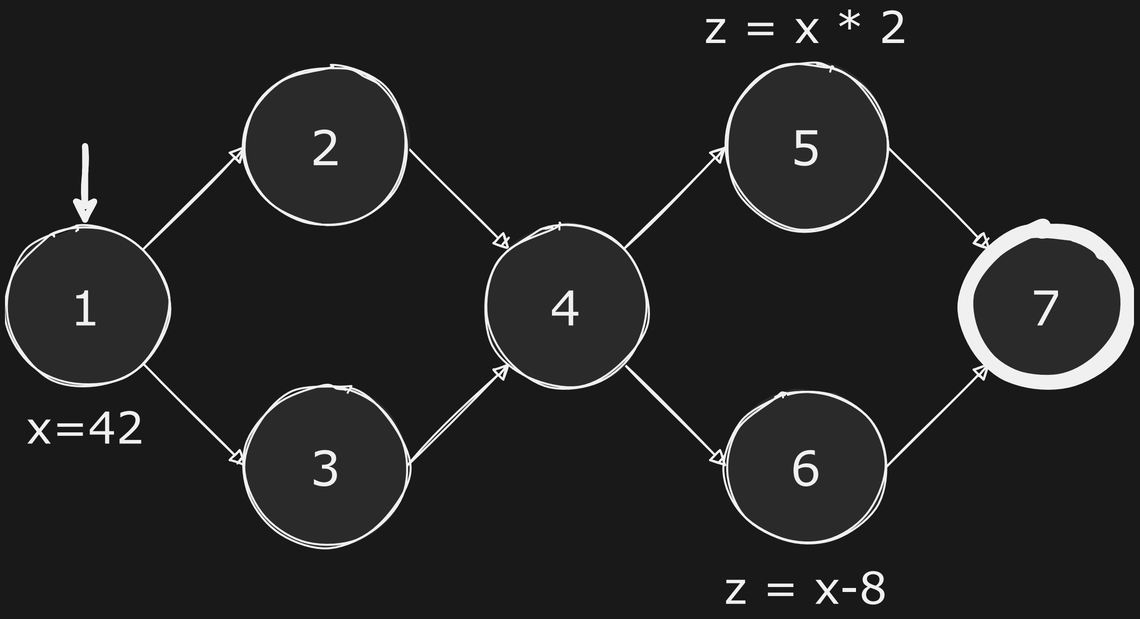
- Remember: du-paths are def-clear!

DATA FLOW TESTING EXAMPLE



DATA FLOW TESTING EXAMPLE

- All Defs for x:
  - [1 2 4 5]



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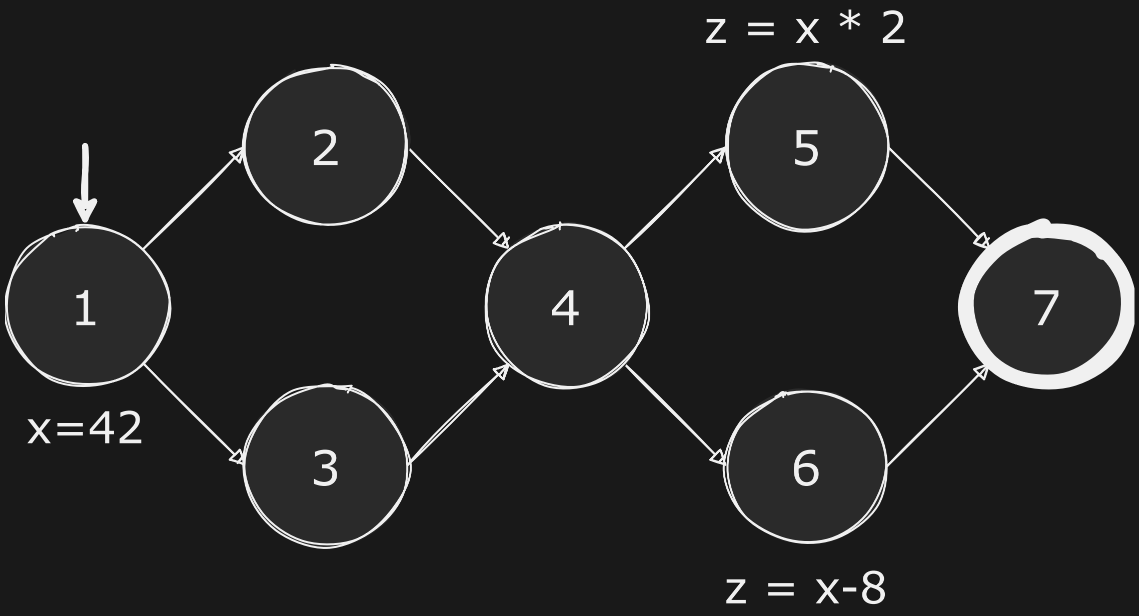

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  - [1 2 4 6]

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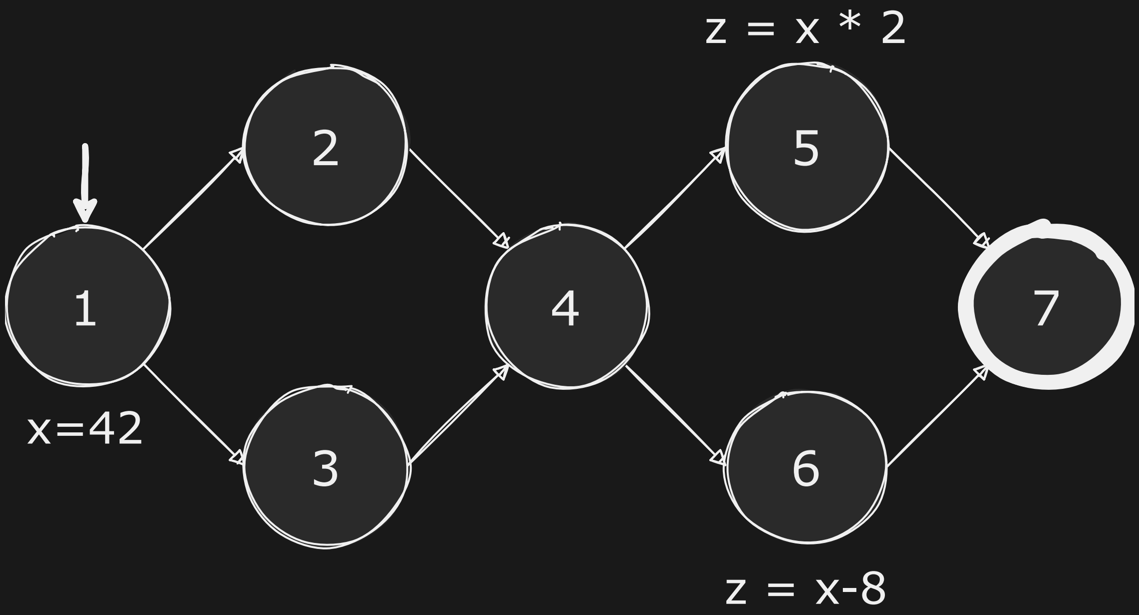

- All Defs for x:
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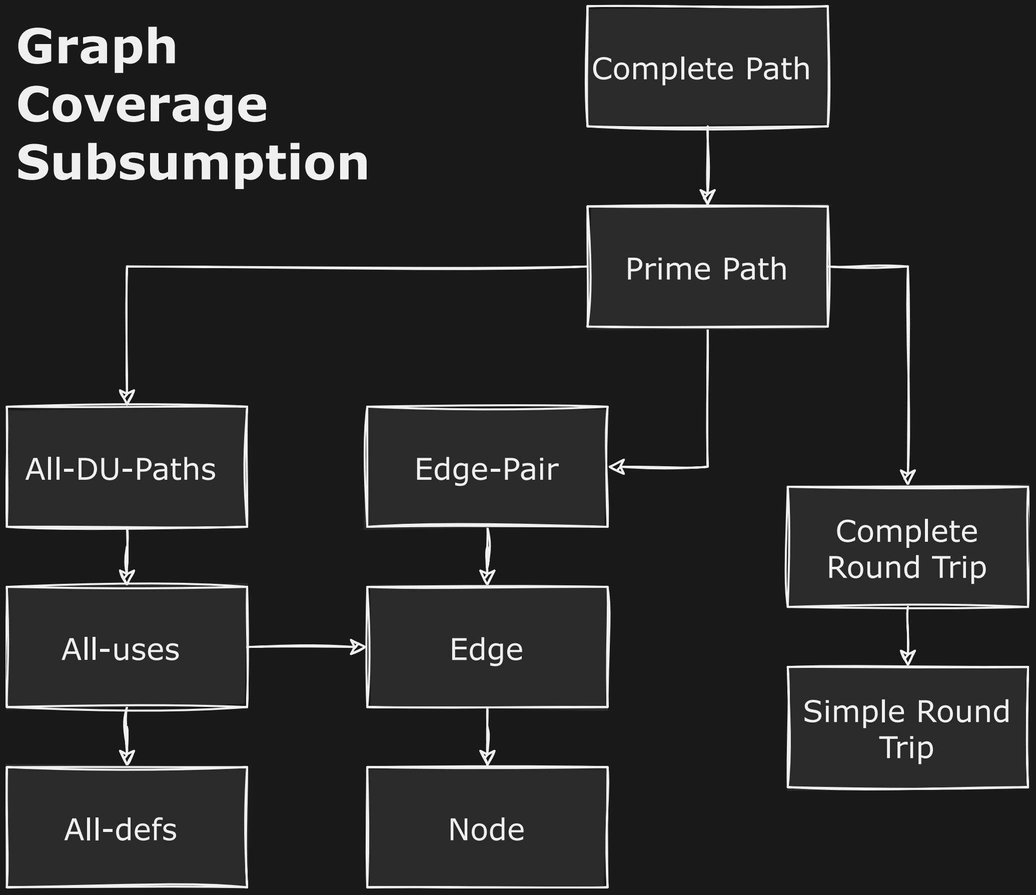
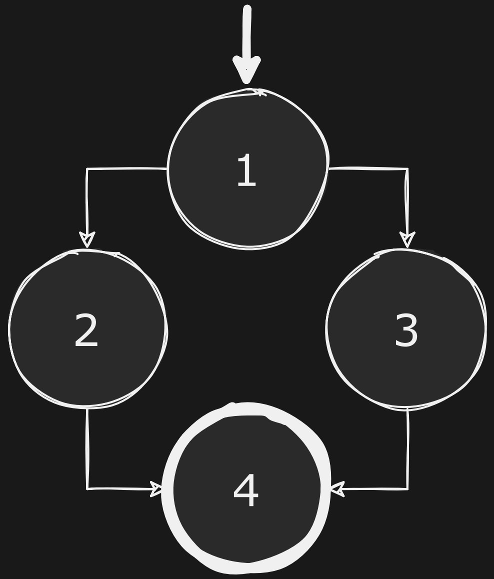
- All Uses for x:
  - [1 2 4 5]
  - [1 2 4 6]
- All Du-Paths for x:
  - [1 2 4 5]
  - [1 3 4 5]
  - [1 2 4 6]
  - [1 3 4 6]

Graph Coverage Subsumption



TRANSLATING SOURCE CODE TO GRAPHS

```
if( x < y)
{
   y =0;
   x = x+1;
}
else
{
   x = y;
}
```



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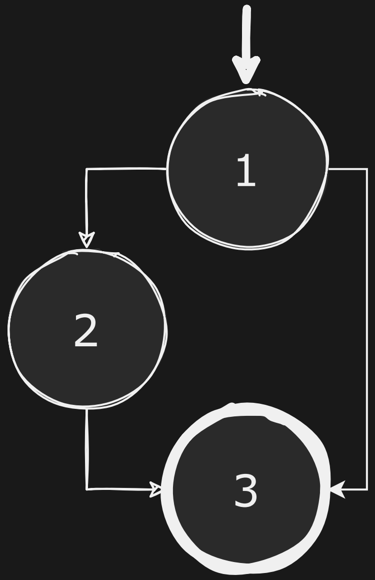
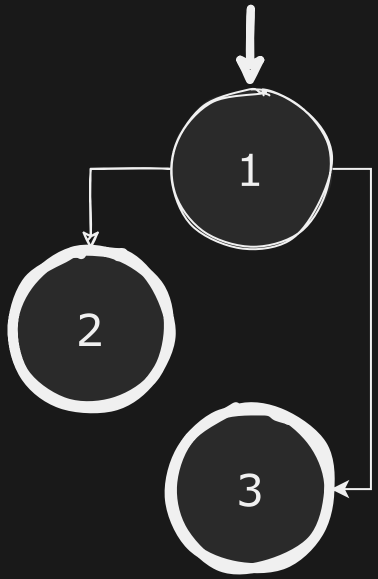
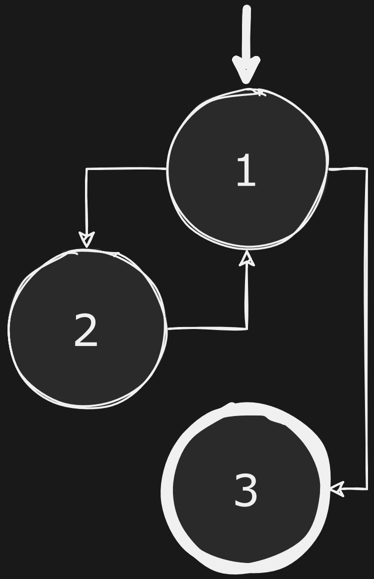


```
if( x < y)
{
   return;
}

print(x);
return;
```



```
x = 0;
while (x<y)
{
   y = f(x,y);
   x = x + 1;
}
```



Or...

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x = 0;
while (x<y)
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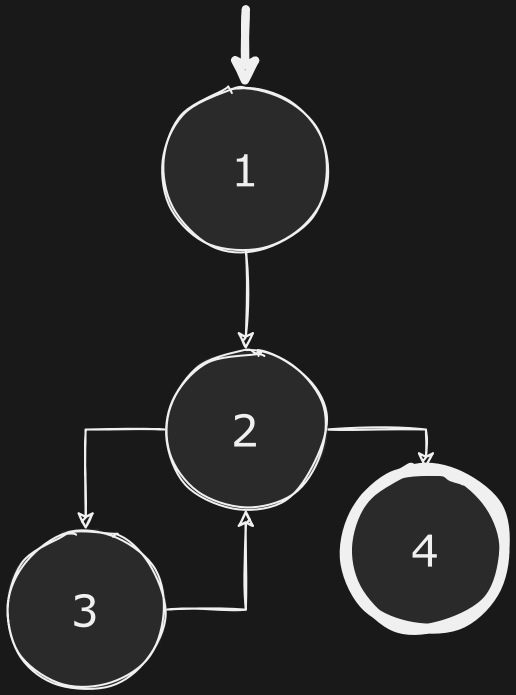

```
for(x=0;x<y;x++)
{
   y = f(x,y);
}
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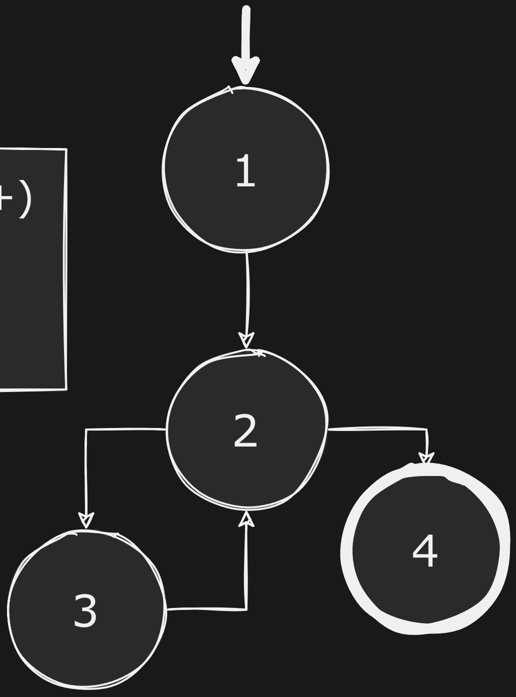
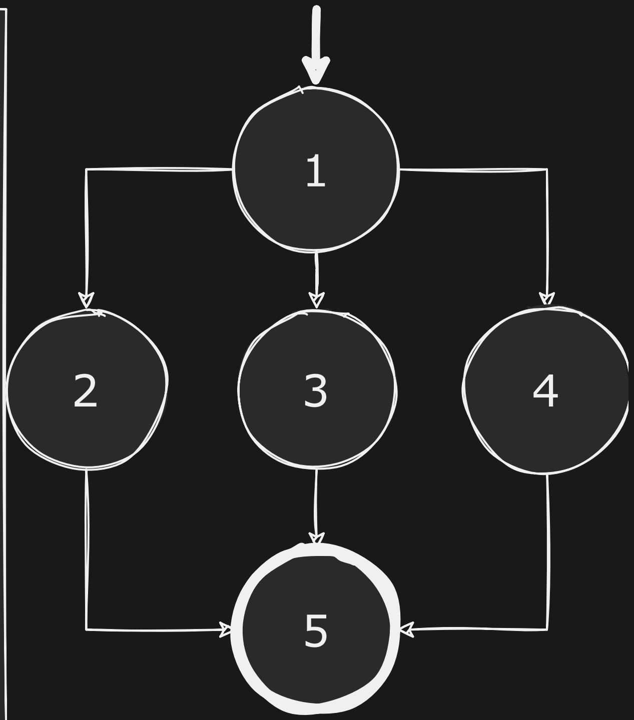
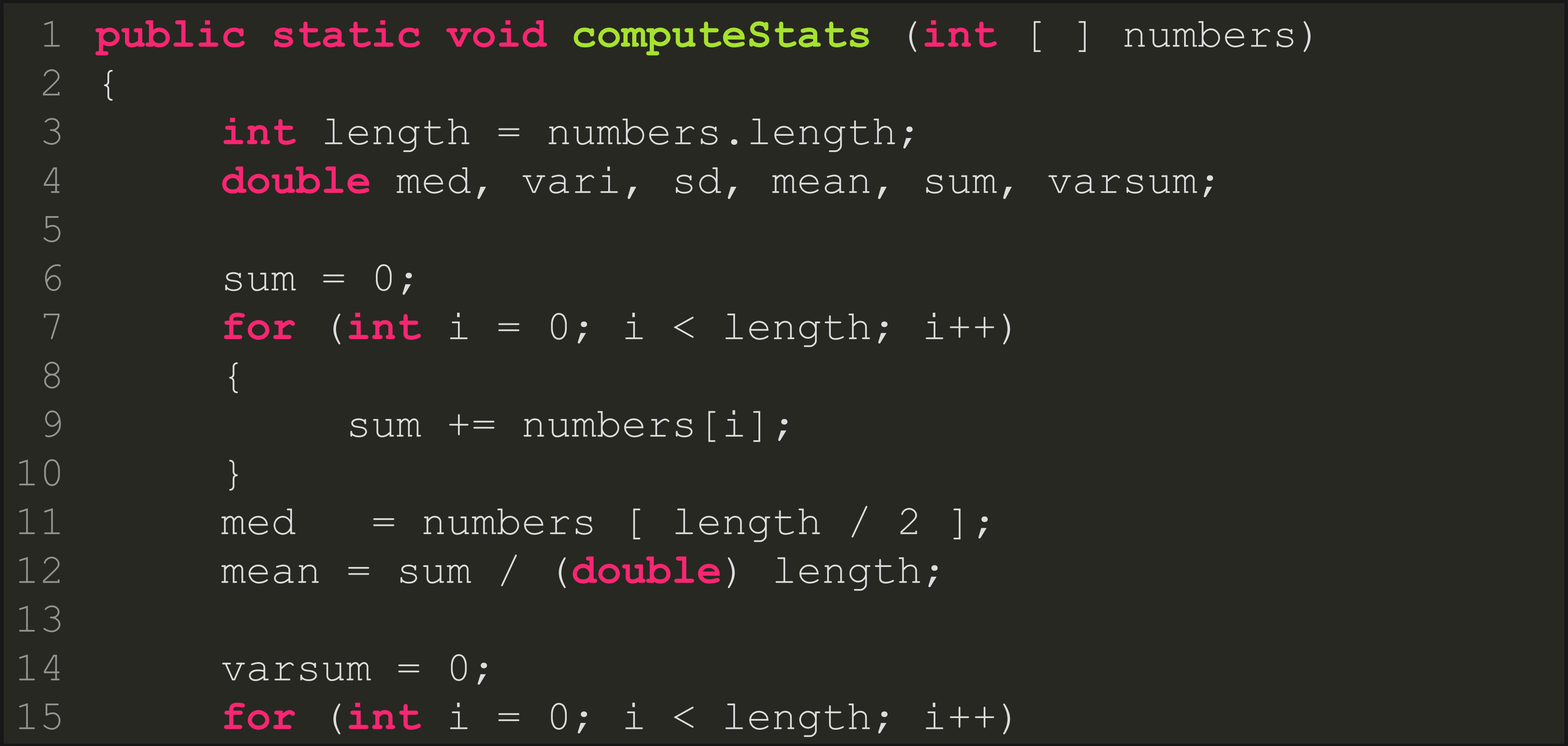


```
read(c);
switch(c)
{
   case 'N':
      y=25;
      break;
   case 'Y':
      y=50;
   default:
      y=0;
      break;
}
print(y);
```





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public static void computeStats (int [ ] numbers)
{
     int length = numbers.length;
     double med, vari, sd, mean, sum, varsum;

     sum = 0;
     for (int i = 0; i < length; i++)
     {
          sum += numbers[i];
     }
     med   = numbers [ length / 2 ];
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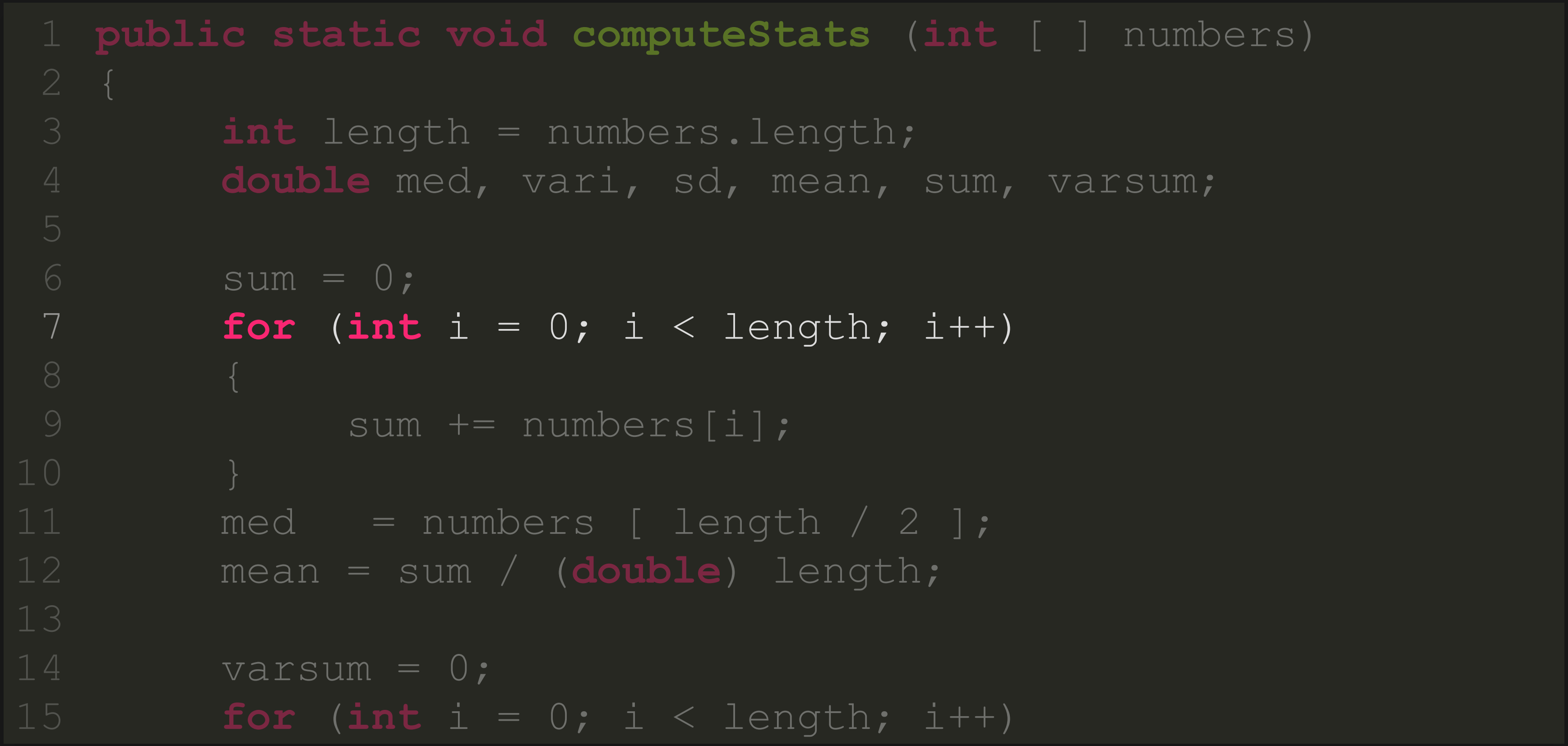

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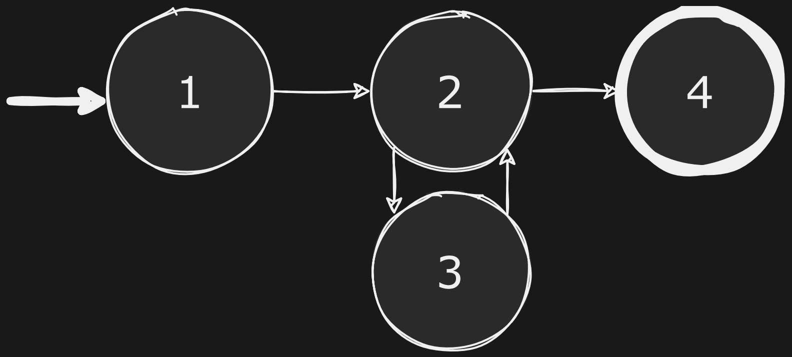
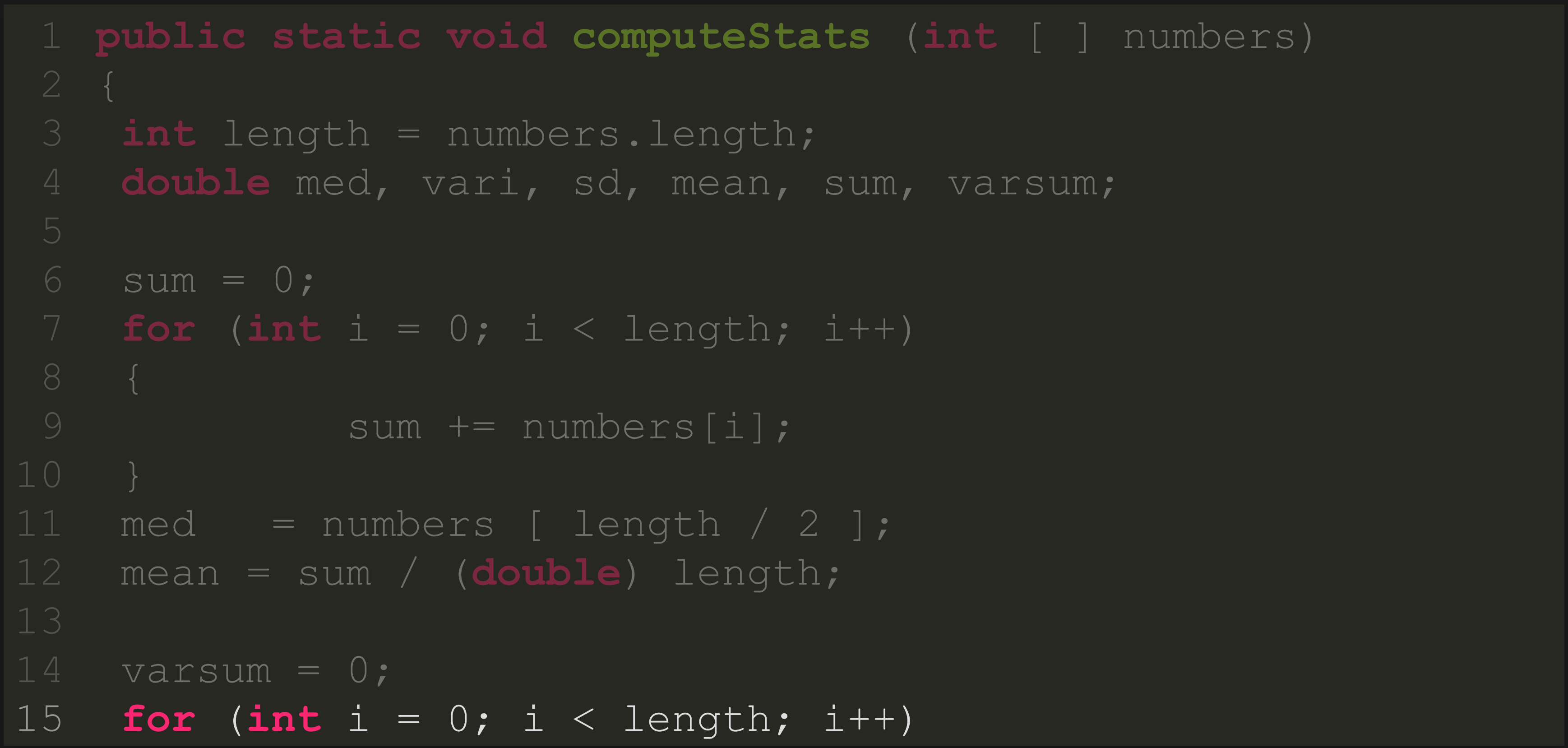
Remember what the for loop looked like in isolation?


1
2
3
4



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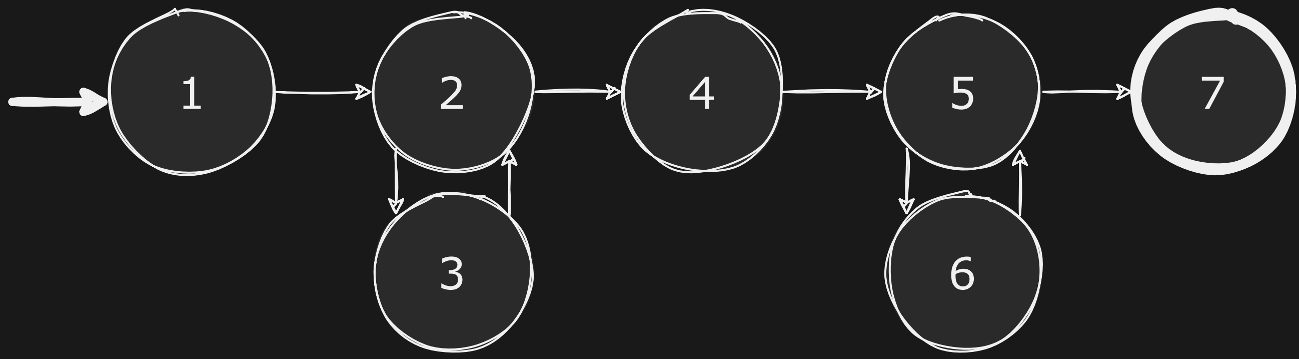
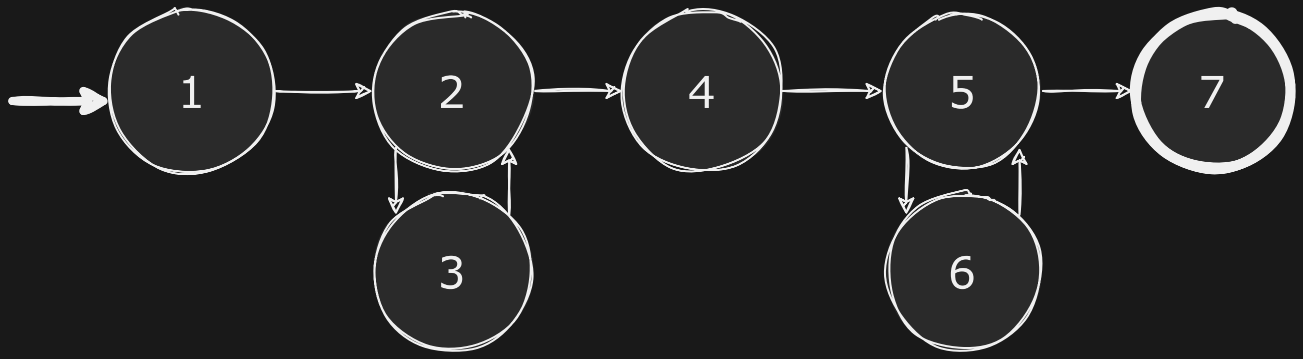
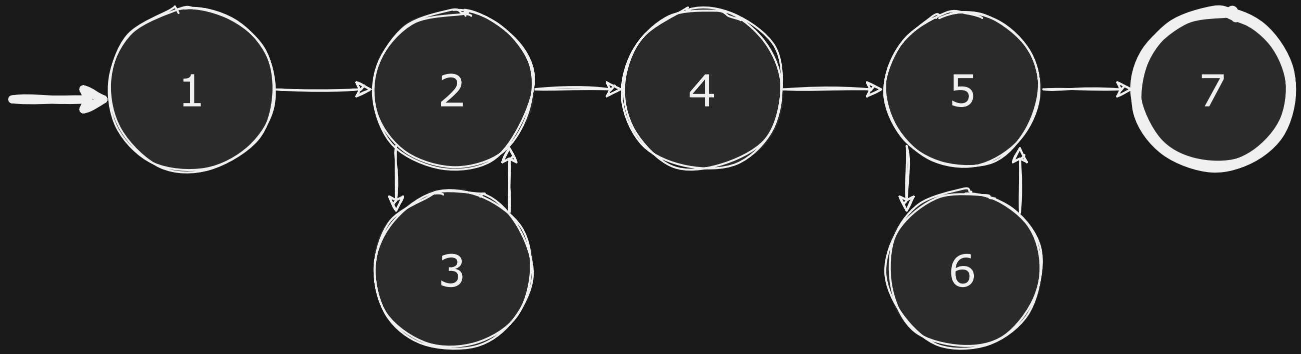



1
2
4
5
7
3
6

PRIME PATH COVERAGE



Test Requirements

-

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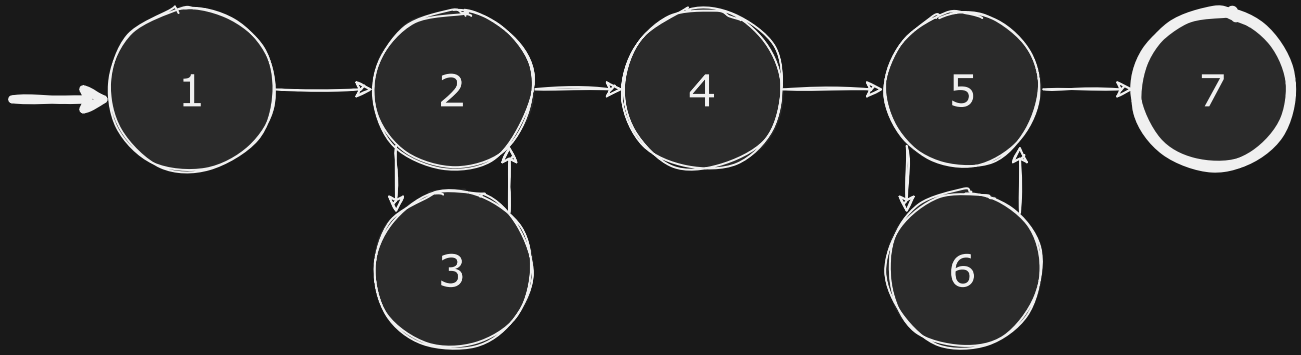

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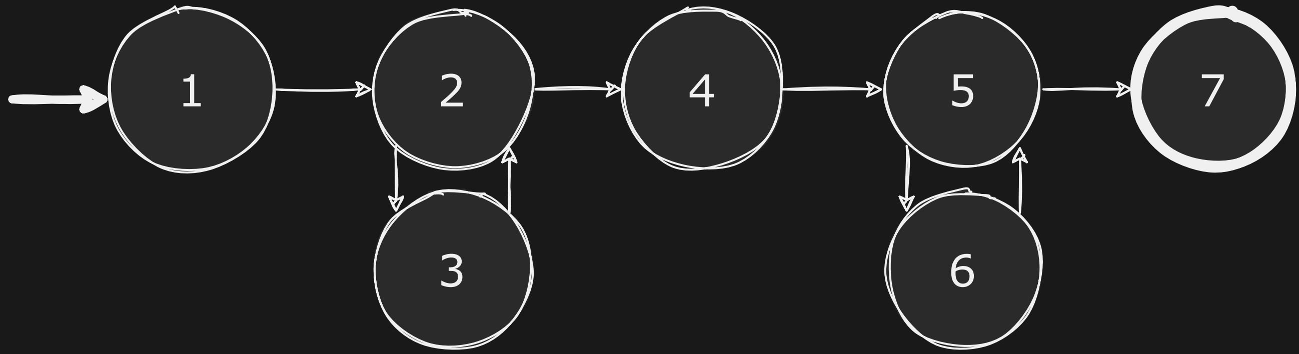

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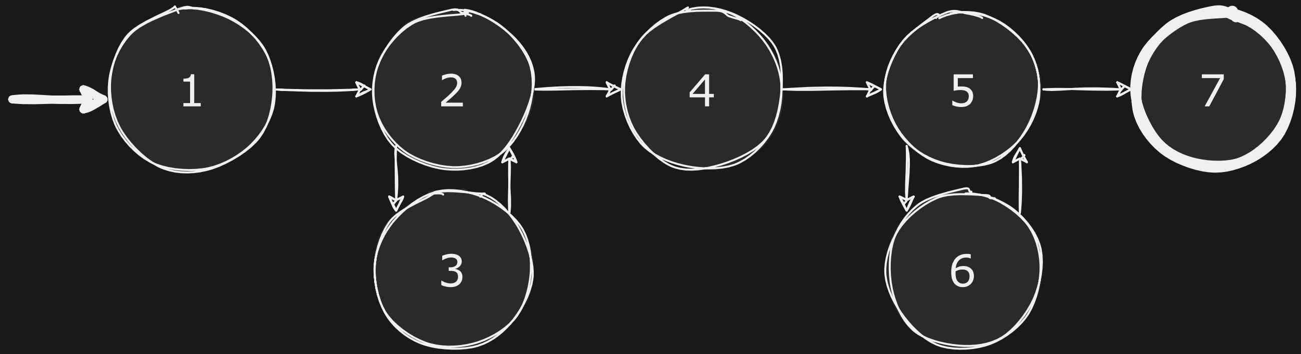

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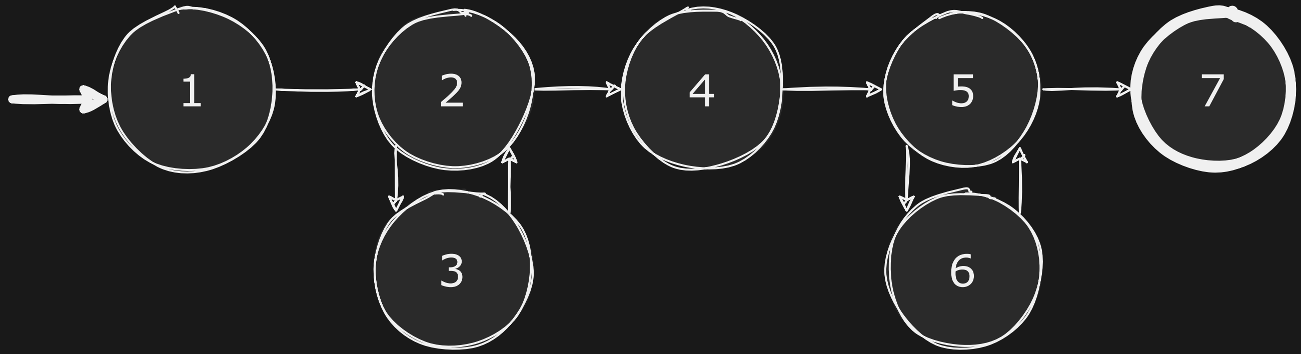

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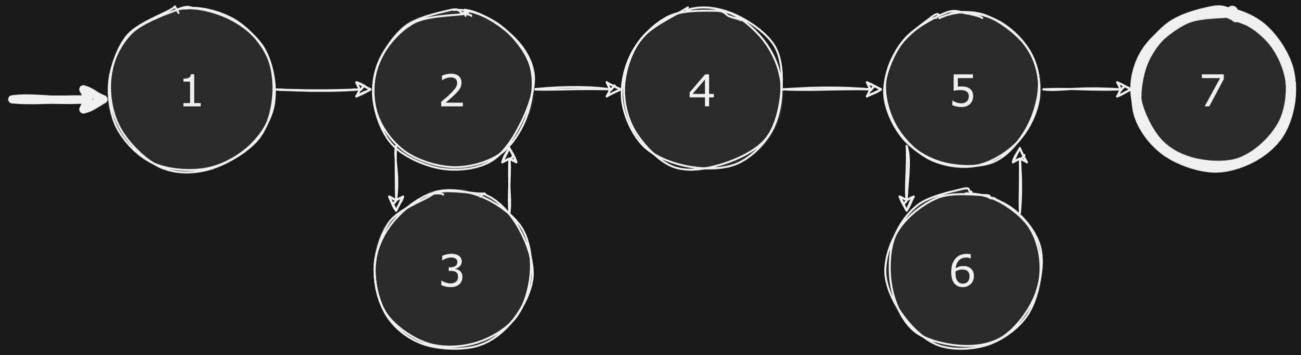
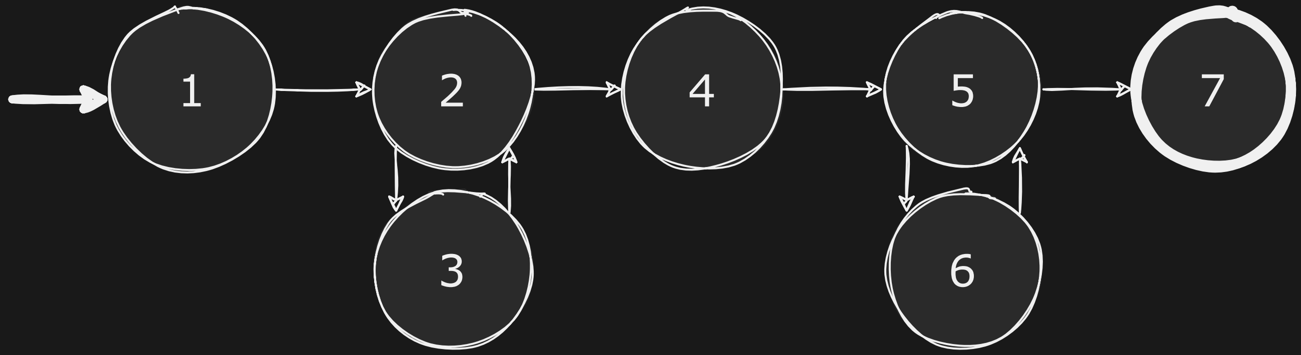


Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7]

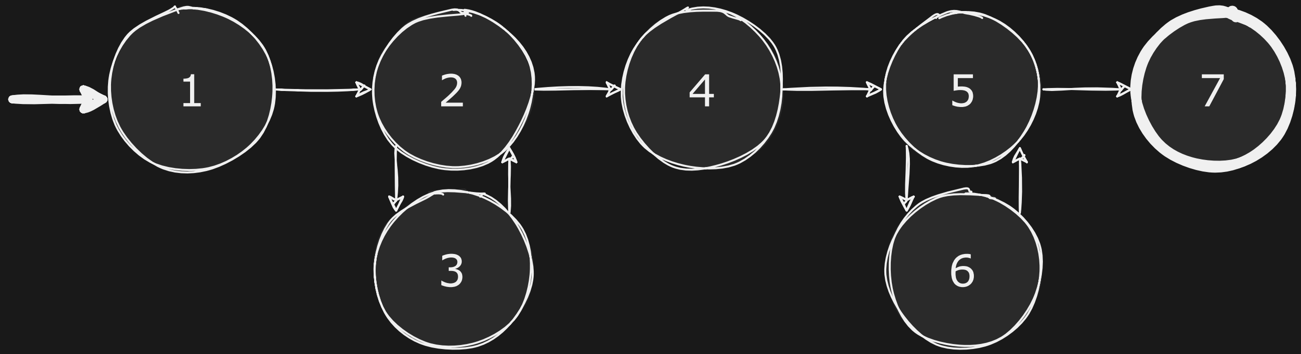
PRIME PATH COVERAGE



Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7] [1 2 4 5 7]

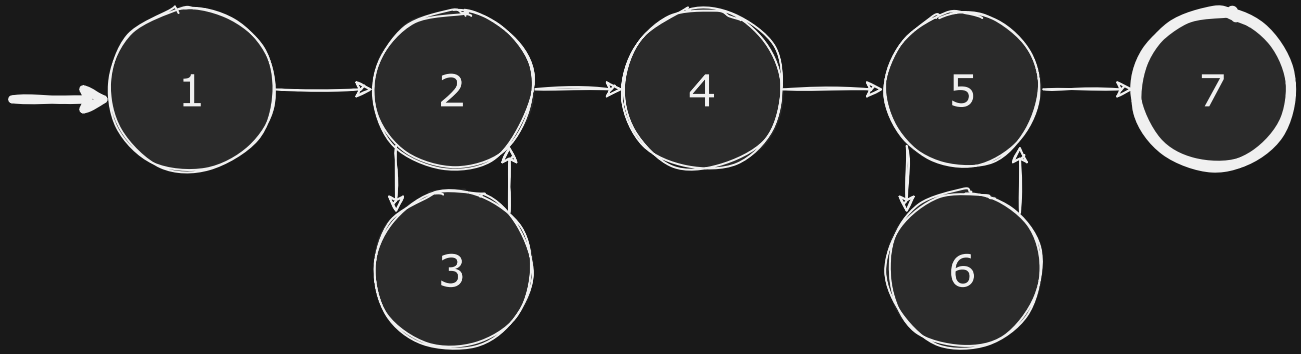
PRIME PATH COVERAGE



Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7] [1 2 4 5 7] [3 2 4 5 7]

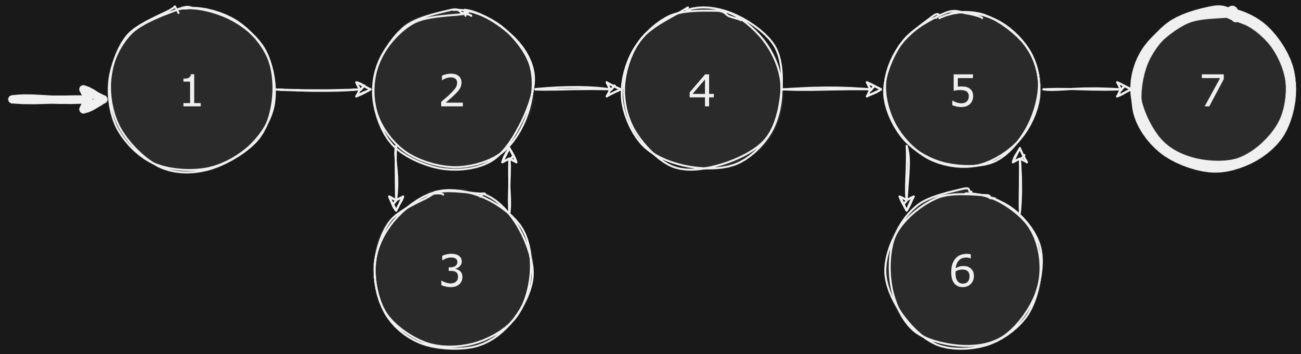
PRIME PATH COVERAGE



Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7] [1 2 4 5 7] [3 2 4 5 7] [1 2 3]

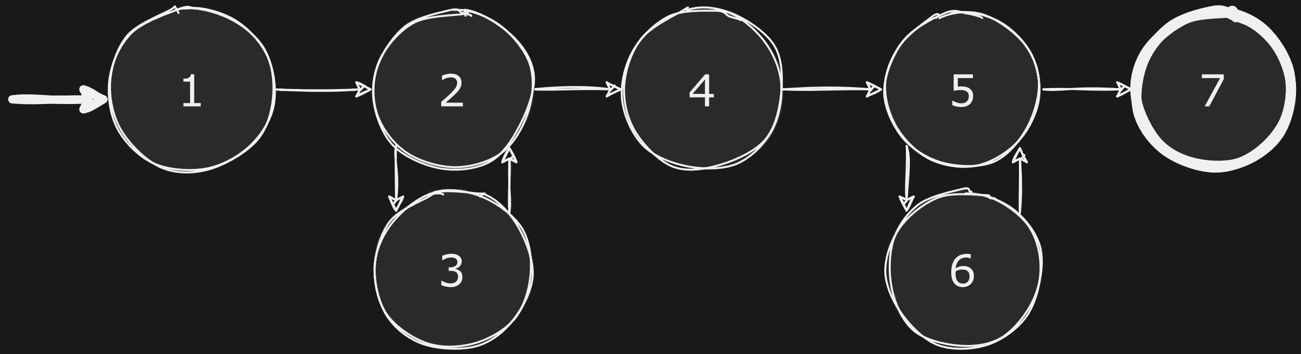
PRIME PATH COVERAGE



Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7] [1 2 4 5 7] [3 2 4 5 7] [1 2 3] [1 2 4 5 6]

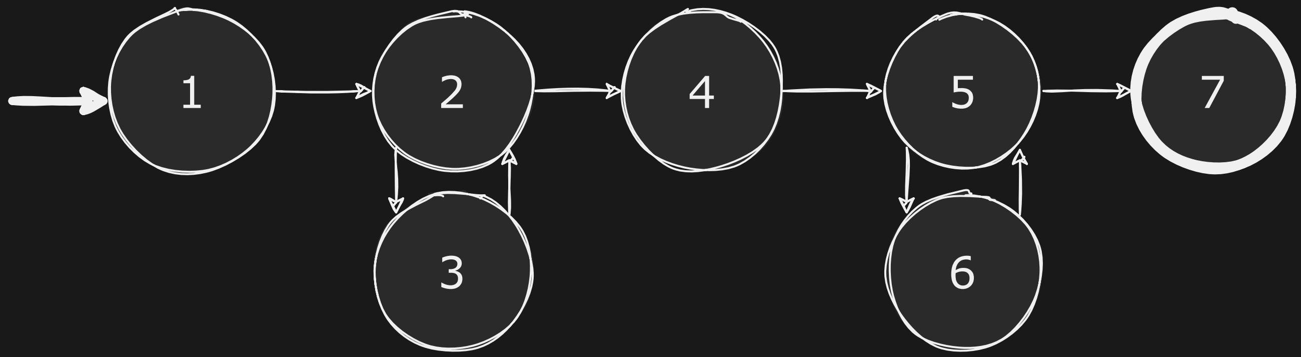
PRIME PATH COVERAGE



Test Requirements

- [2 3 2] [3 2 3] [5 6 5] [6 5 6] [6 5 7] [1 2 4 5 7] [3 2 4 5 7] [1 2 3] [1 2 4 5 6] [3 2 4 5 6]

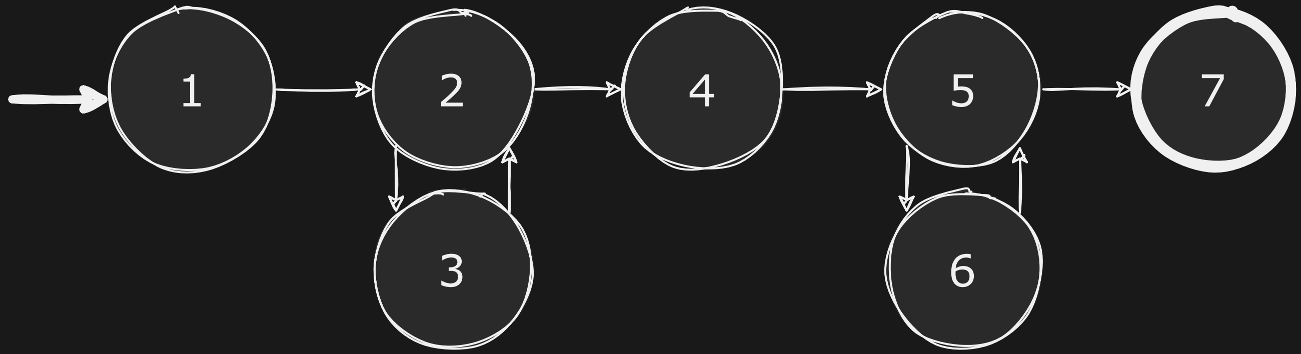
PRIME PATH COVERAGE



Test Paths

-

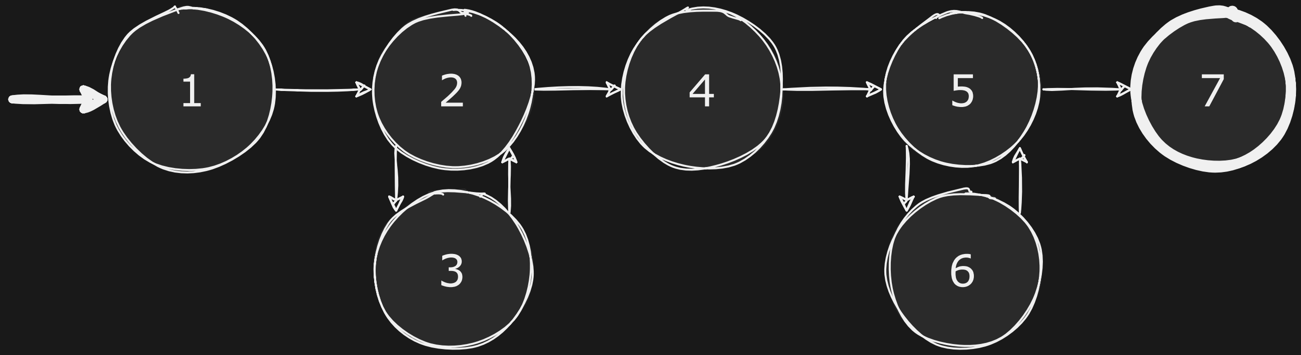
PRIME PATH COVERAGE



Test Paths

- [1 2 3 2 4 5 6 5 7]

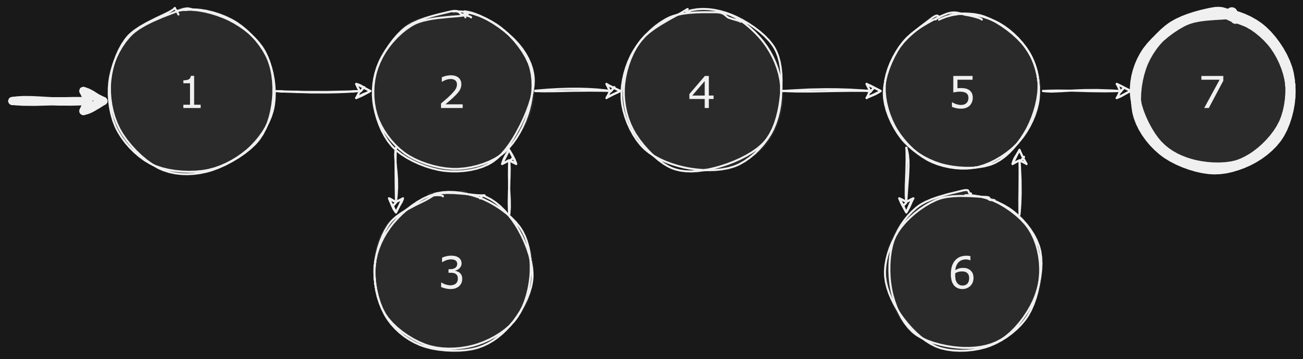
PRIME PATH COVERAGE



Test Paths

- [1 2 3 2 4 5 6 5 7] [1 2 4 5 7]

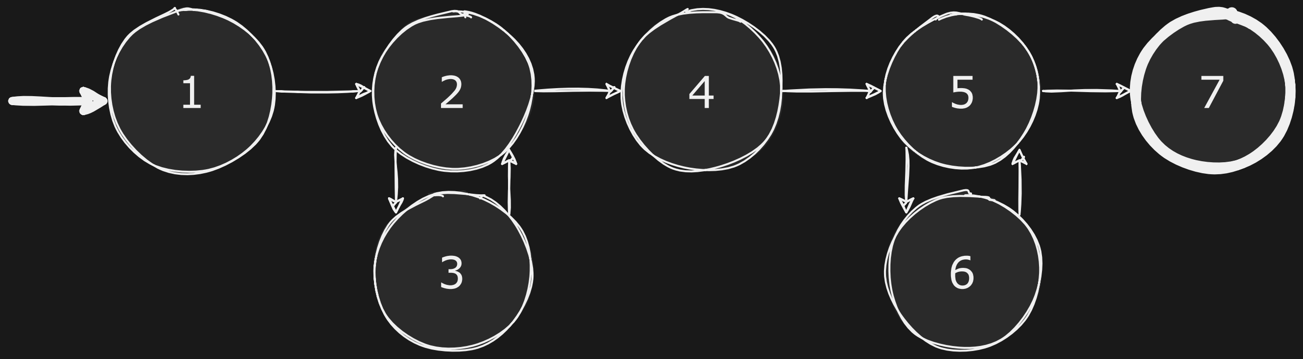
PRIME PATH COVERAGE



Test Paths

- [1 2 3 2 4 5 6 5 7] [1 2 4 5 7] [1 2 4 5 6 5 7]

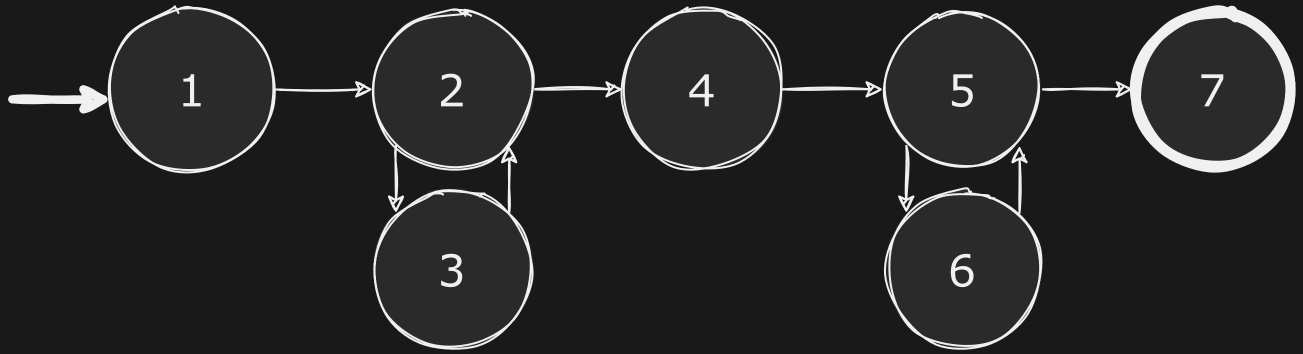
PRIME PATH COVERAGE



Test Paths

- [1 2 3 2 4 5 6 5 7] [1 2 4 5 7] [1 2 4 5 6 5 7] [1 2 3 2 4 5 7]

PRIME PATH COVERAGE



Test Paths

- [1 2 3 2 4 5 6 5 7] [1 2 4 5 7] [1 2 4 5 6 5 7] [1 2 3 2 4 5 7] [1 2 3 2 3 2 4 5 6 5 6 5 7]

DATA FLOW AND SOURCE

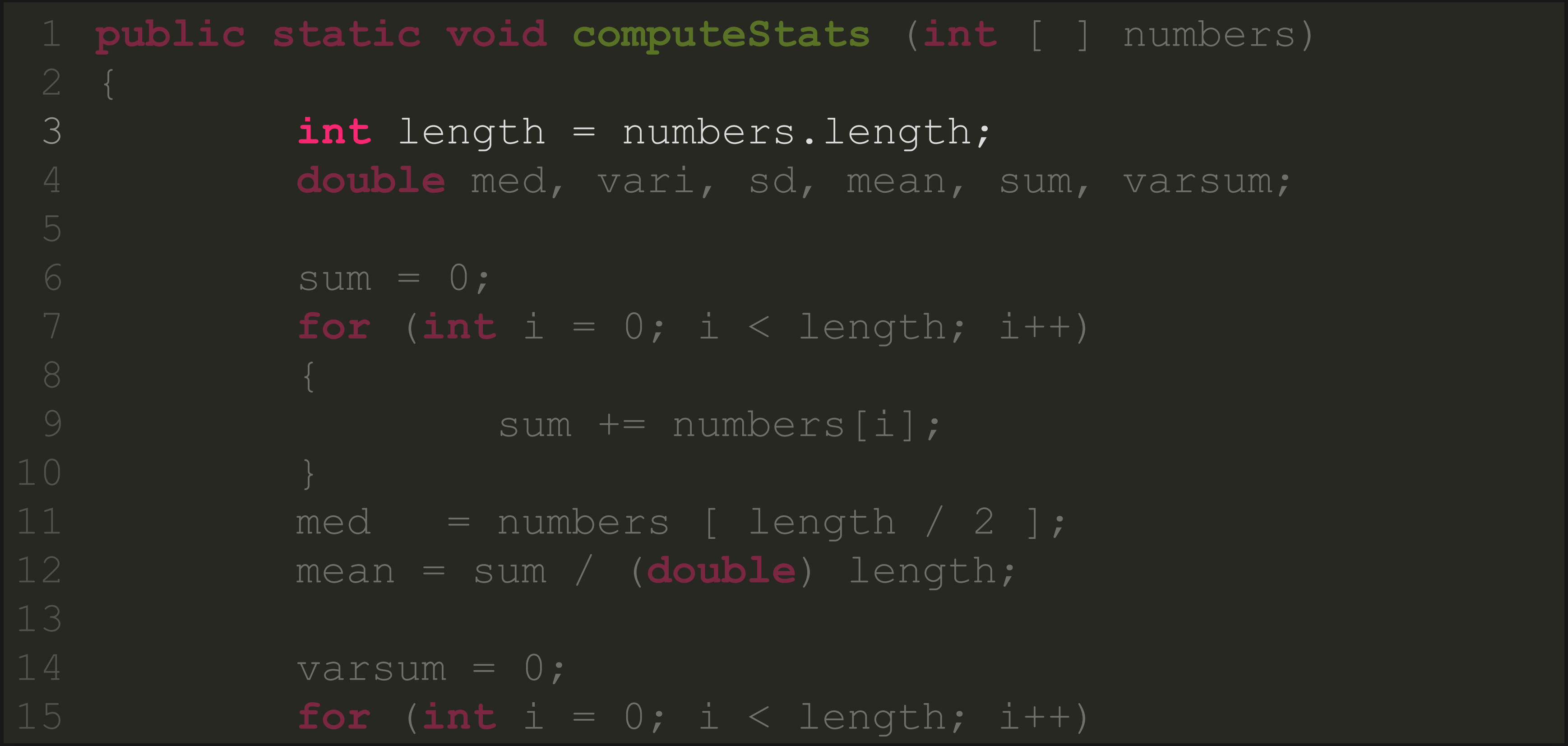
DEFS

```
public static void computeStats (int [ ] numbers)
{
        int length = numbers.length;
        double med, vari, sd, mean, sum, varsum;

        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

DEFS



```java
public static void computeStats (int [ ] numbers)
{
        int length = numbers.length;
        double med, vari, sd, mean, sum, varsum;

        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

DEFS

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        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

DEFS

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        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

DEFS

```
{
        int length = numbers.length;
        double med, vari, sd, mean, sum, varsum;

        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
        {
```

DEFS

```
double med, vari, sd, mean, sum, varsum;

sum = 0;
for (int i = 0; i < length; i++)
{
        sum += numbers[i];
}
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
```

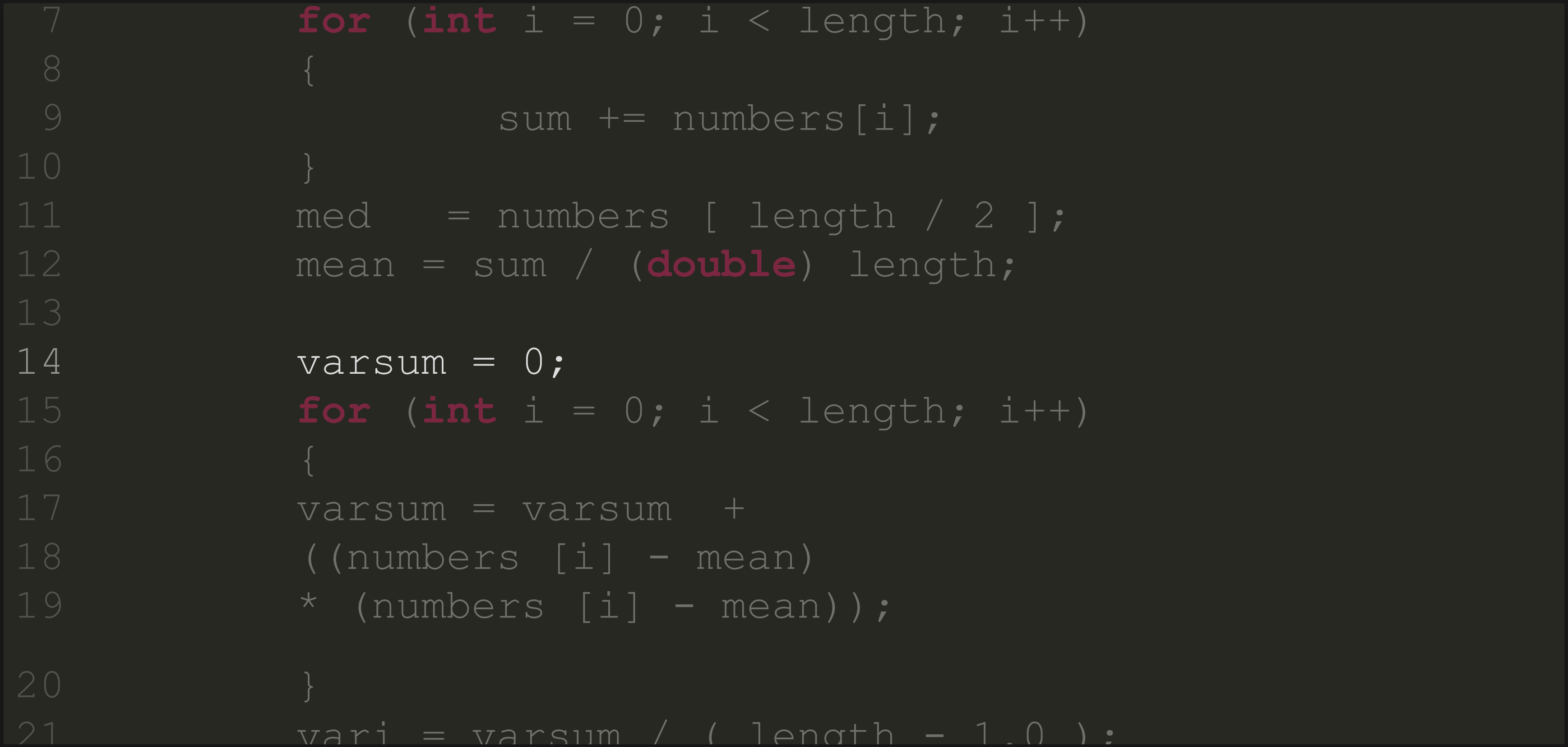
DEFS

```

sum = 0;
for (int i = 0; i < length; i++)
{
        sum += numbers[i];
}
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
*  (numbers [i] - mean));
```

DEFS



```
for (int i = 0; i < length; i++)
{
        sum += numbers[i];
}
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
```

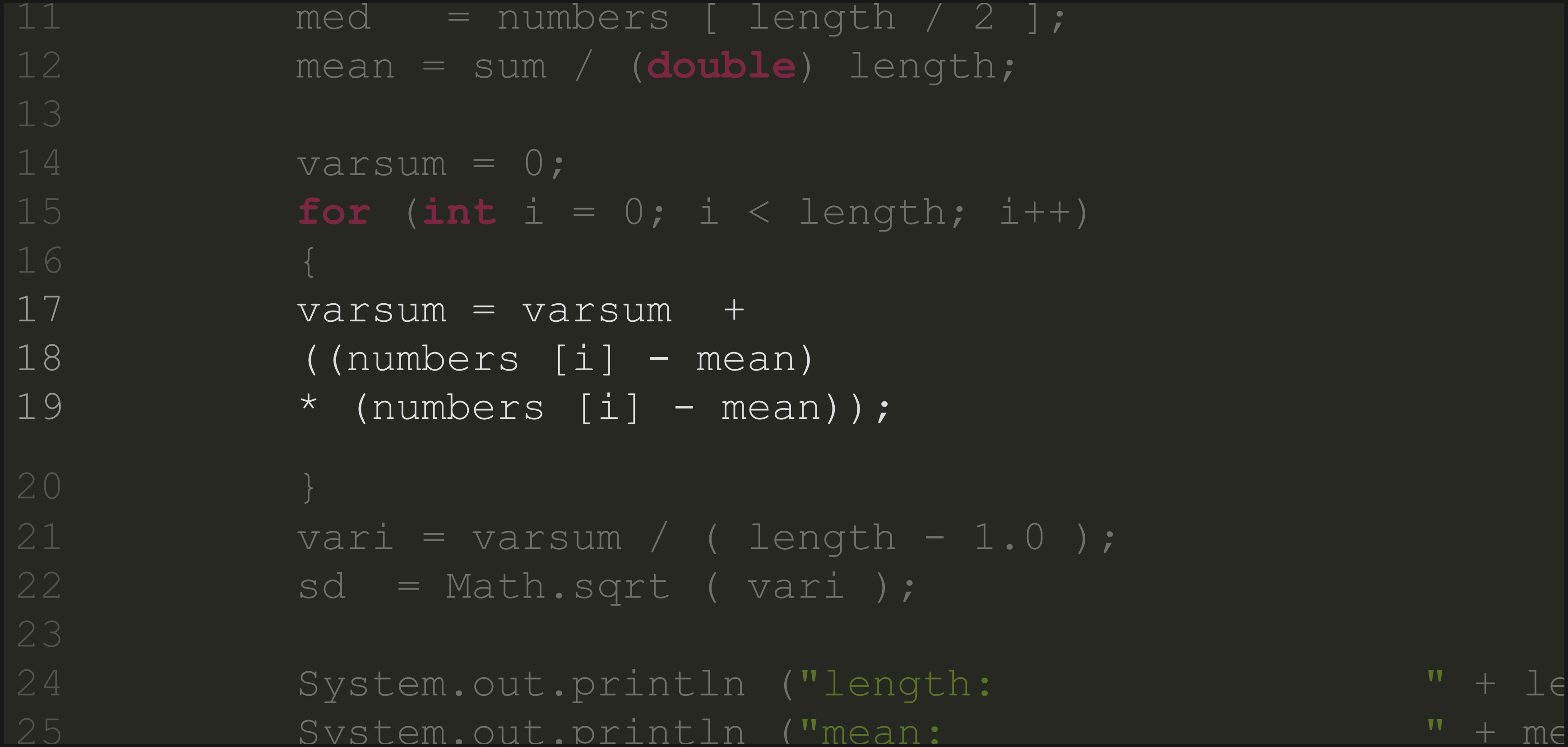
DEFS

```
{
        sum += numbers[i];
}
med    = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd   = Math.sqrt ( vari );
```

DEFS



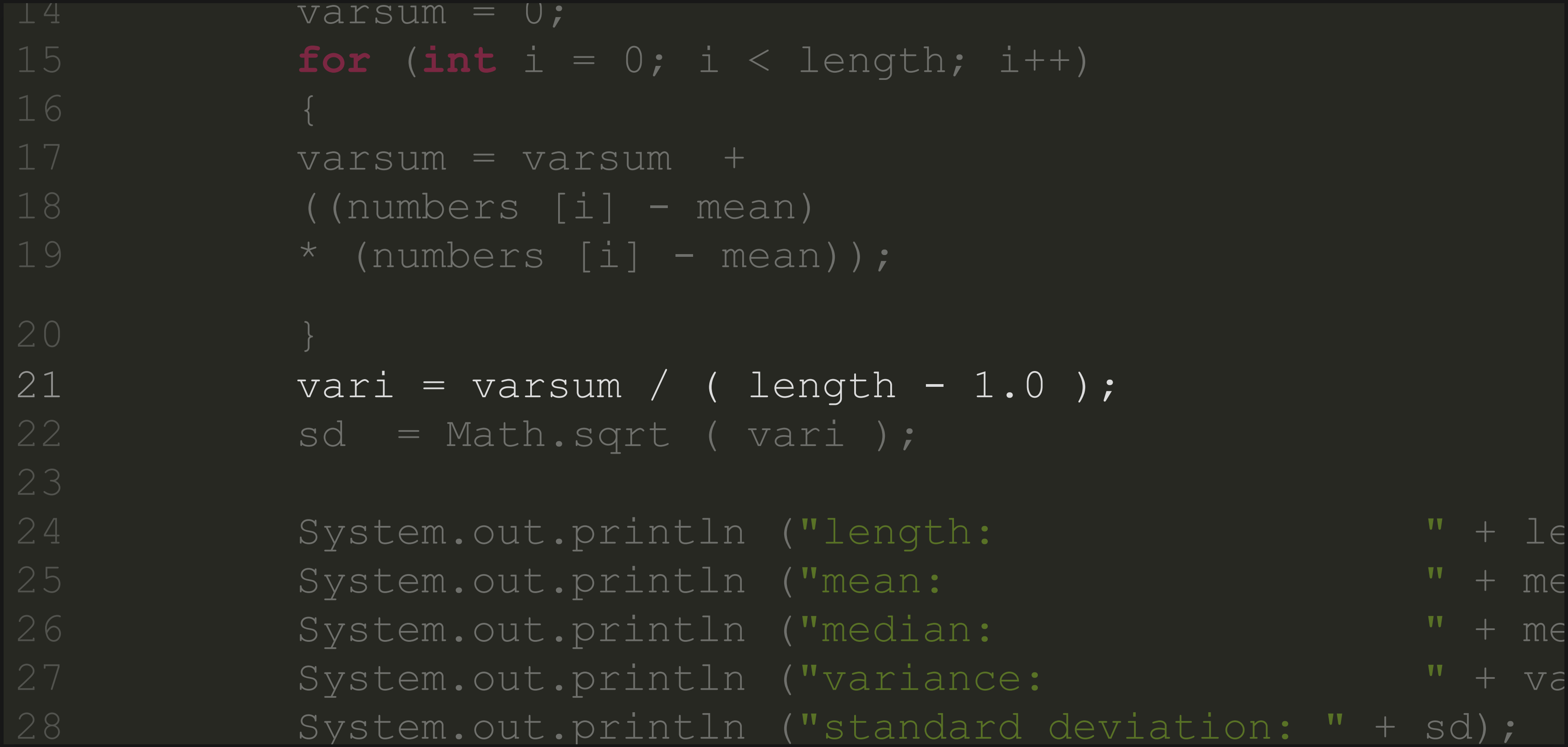
```
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd  = Math.sqrt ( vari );

System.out.println ("length:                 " + le
System.out.println ("mean:                   " + me
```

DEFS

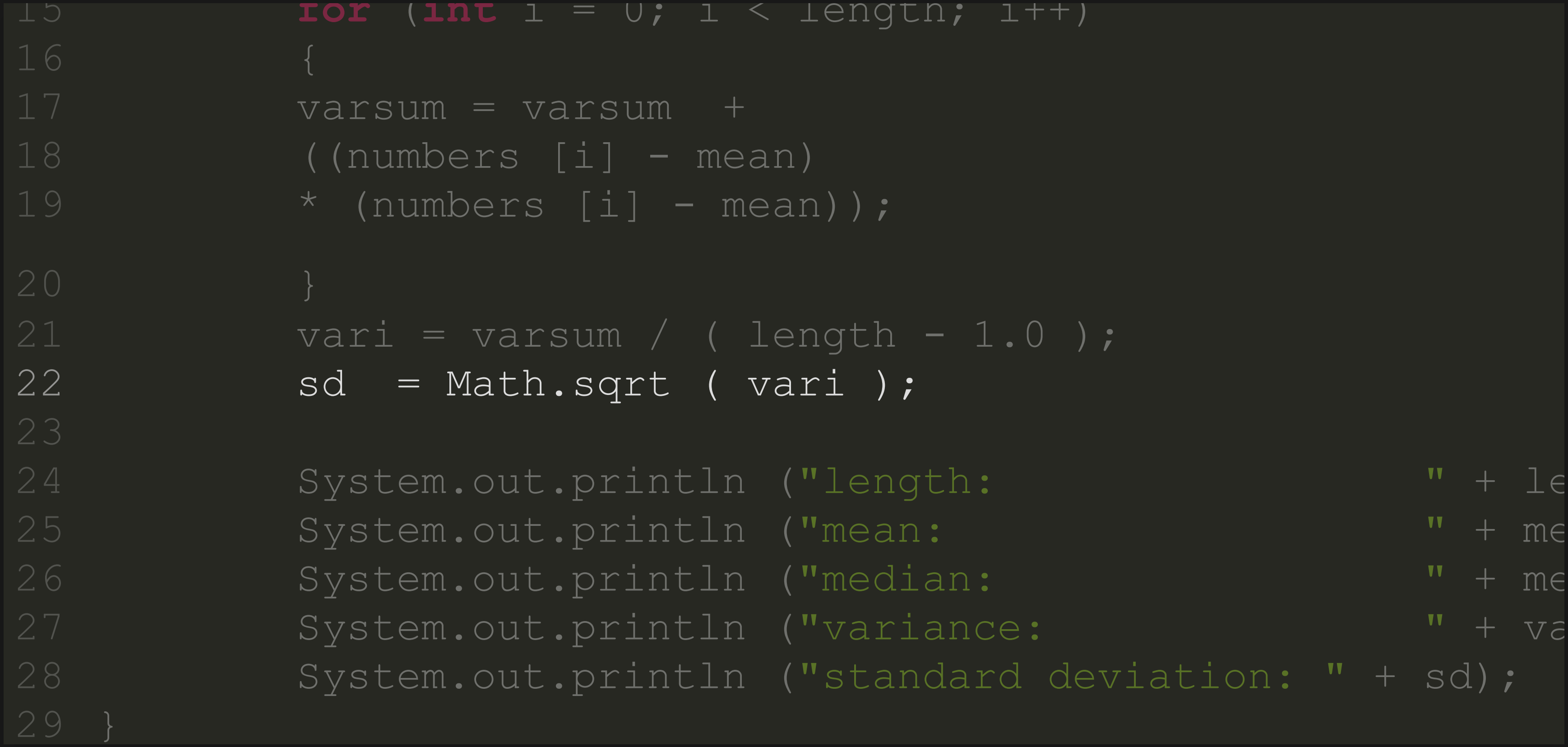


```
varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
*  (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd  = Math.sqrt ( vari );

System.out.println ("length:                 " + le
System.out.println ("mean:                   " + me
System.out.println ("median:                 " + me
System.out.println ("variance:               " + va
System.out.println ("standard deviation: " + sd);
```

DEFS



```
        for (int i = 0; i < length; i++)
        {
        varsum = varsum  +
        ((numbers [i] - mean)
        * (numbers [i] - mean));

        }
        vari = varsum / ( length - 1.0 );
        sd  = Math.sqrt ( vari );

        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```

USES

```
public static void computeStats (int [ ] numbers)
{
        int length = numbers.length;
        double med, vari, sd, mean, sum, varsum;

        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

USES

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```

USES

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        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
        {
```
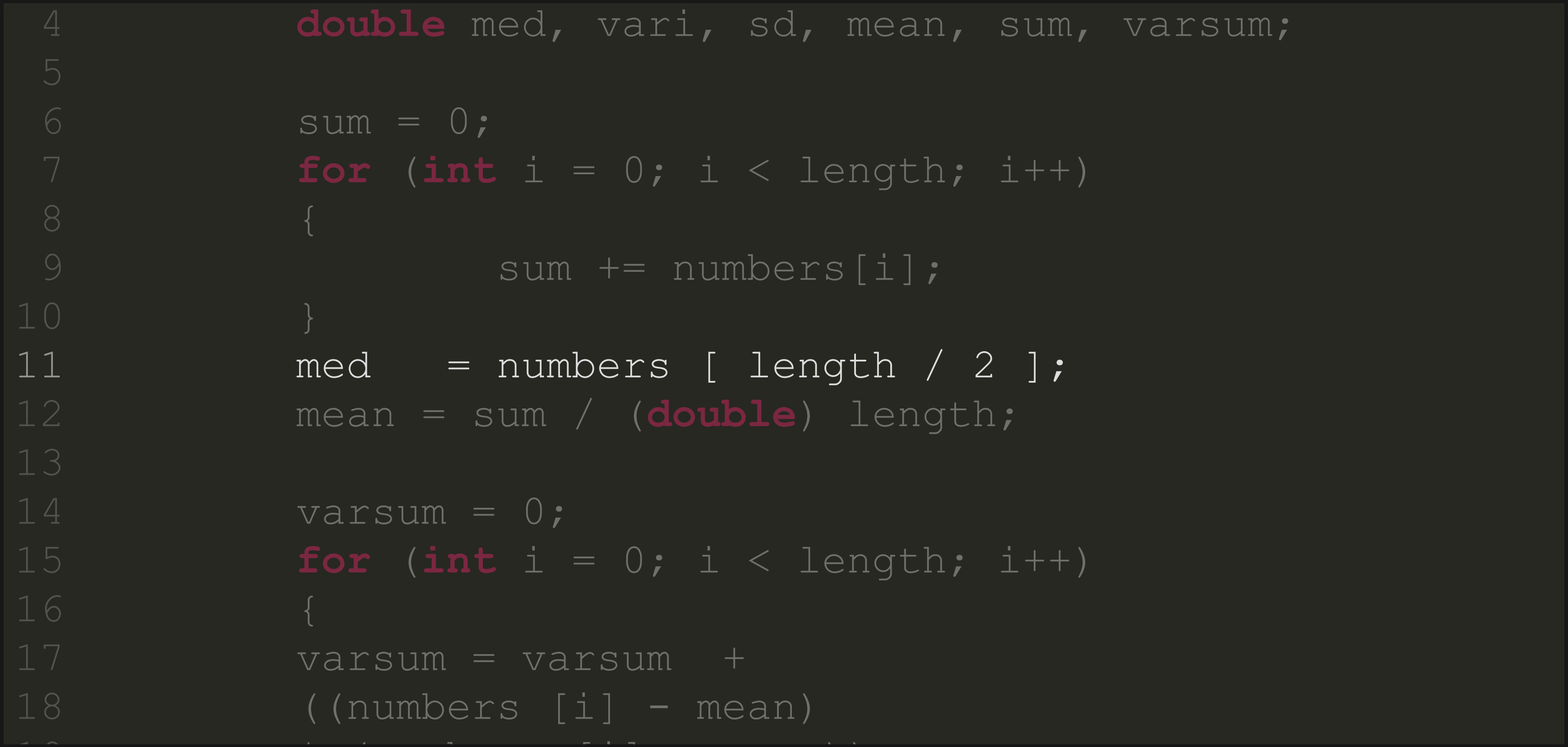

USES



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sum = 0;
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varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
```

USES

```

sum = 0;
for (int i = 0; i < length; i++)
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varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));
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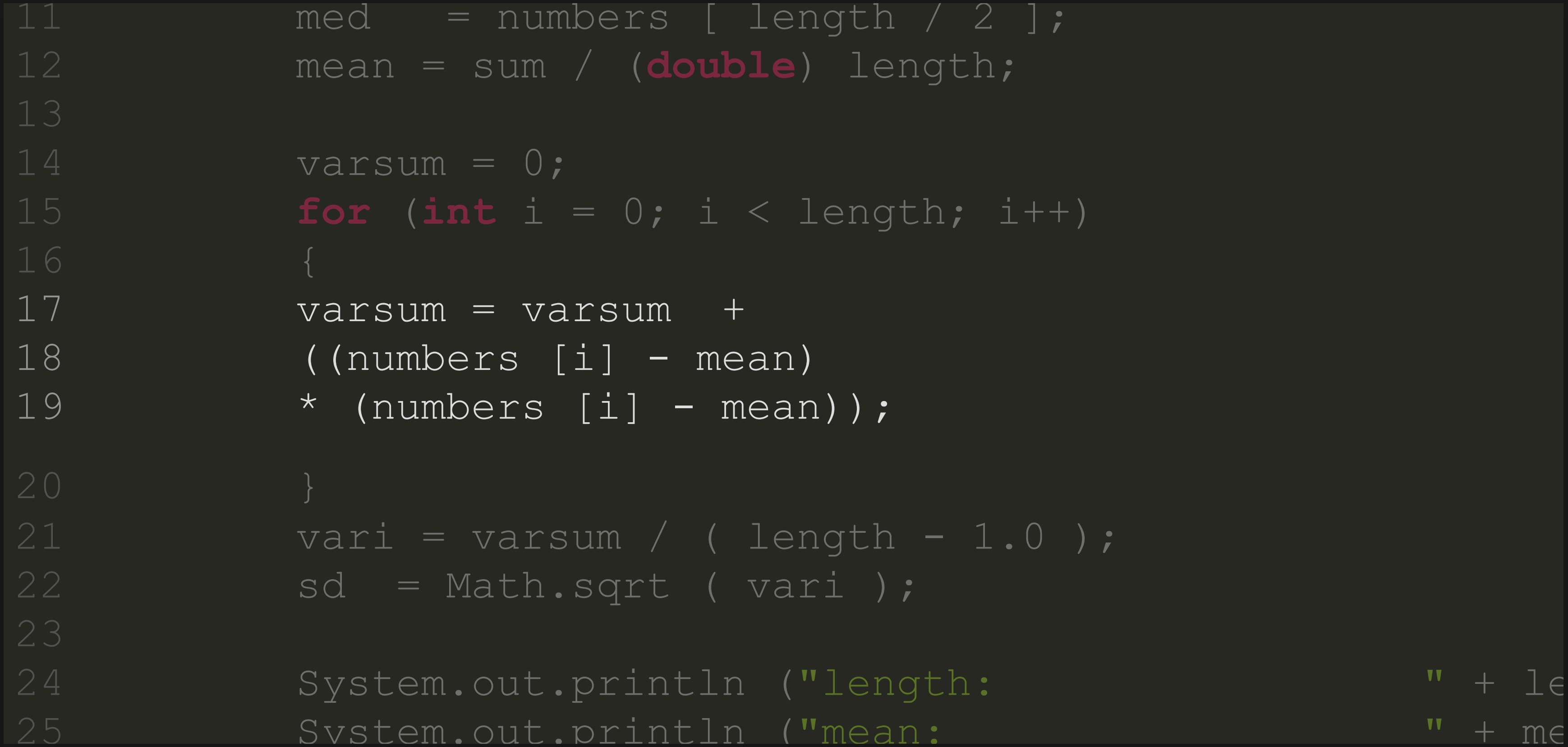
USES

```
{
        sum += numbers[i];
}
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd  = Math.sqrt ( vari );
```

USES



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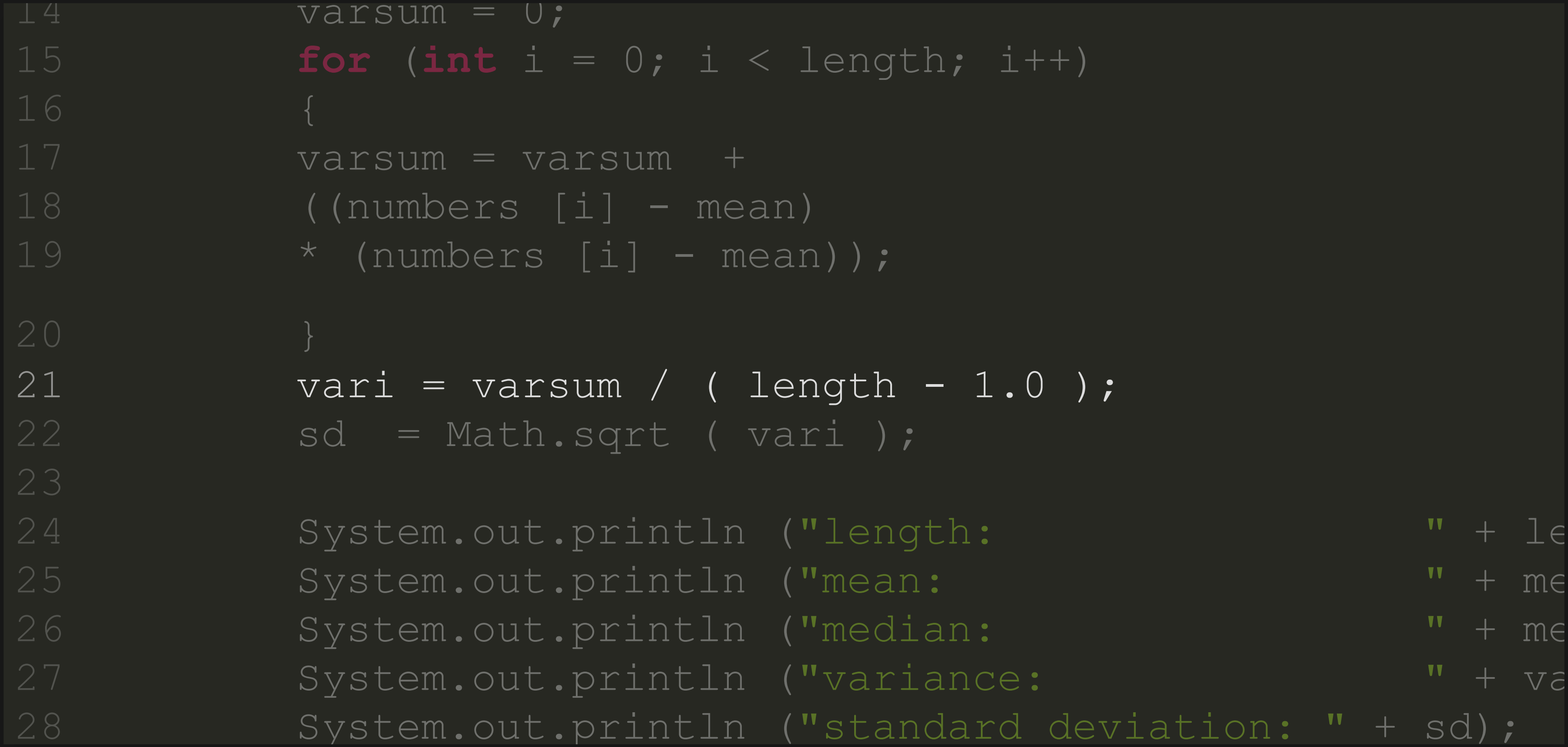
varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd  = Math.sqrt ( vari );

System.out.println ("length:                    " + le
System.out.println ("mean:                      " + me
```

USES



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varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
* (numbers [i] - mean));

}
vari = varsum / ( length - 1.0 );
sd  = Math.sqrt ( vari );

System.out.println ("length:                  " + le
System.out.println ("mean:                    " + me
System.out.println ("median:                  " + me
System.out.println ("variance:                " + va
System.out.println ("standard deviation: " + sd);
```
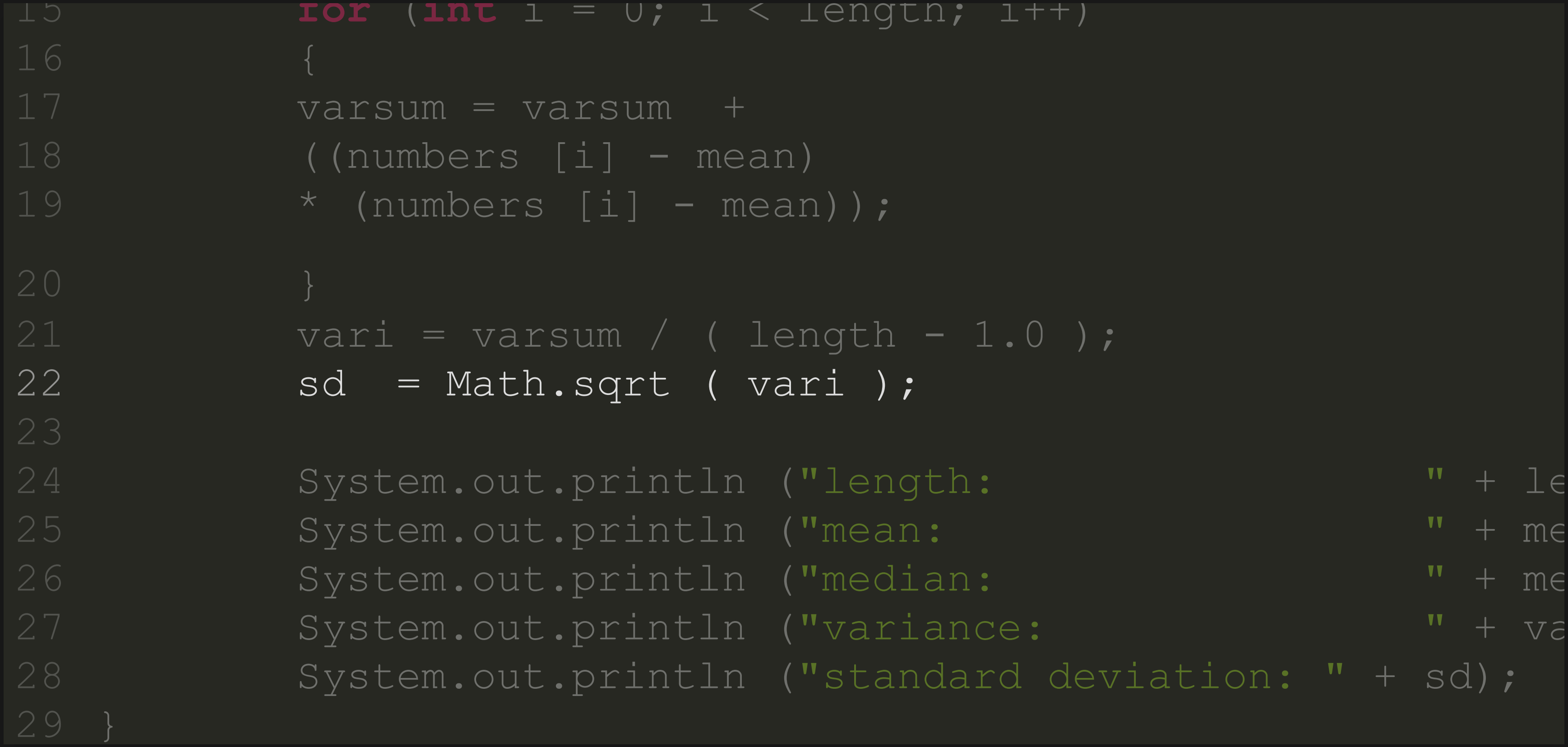

USES



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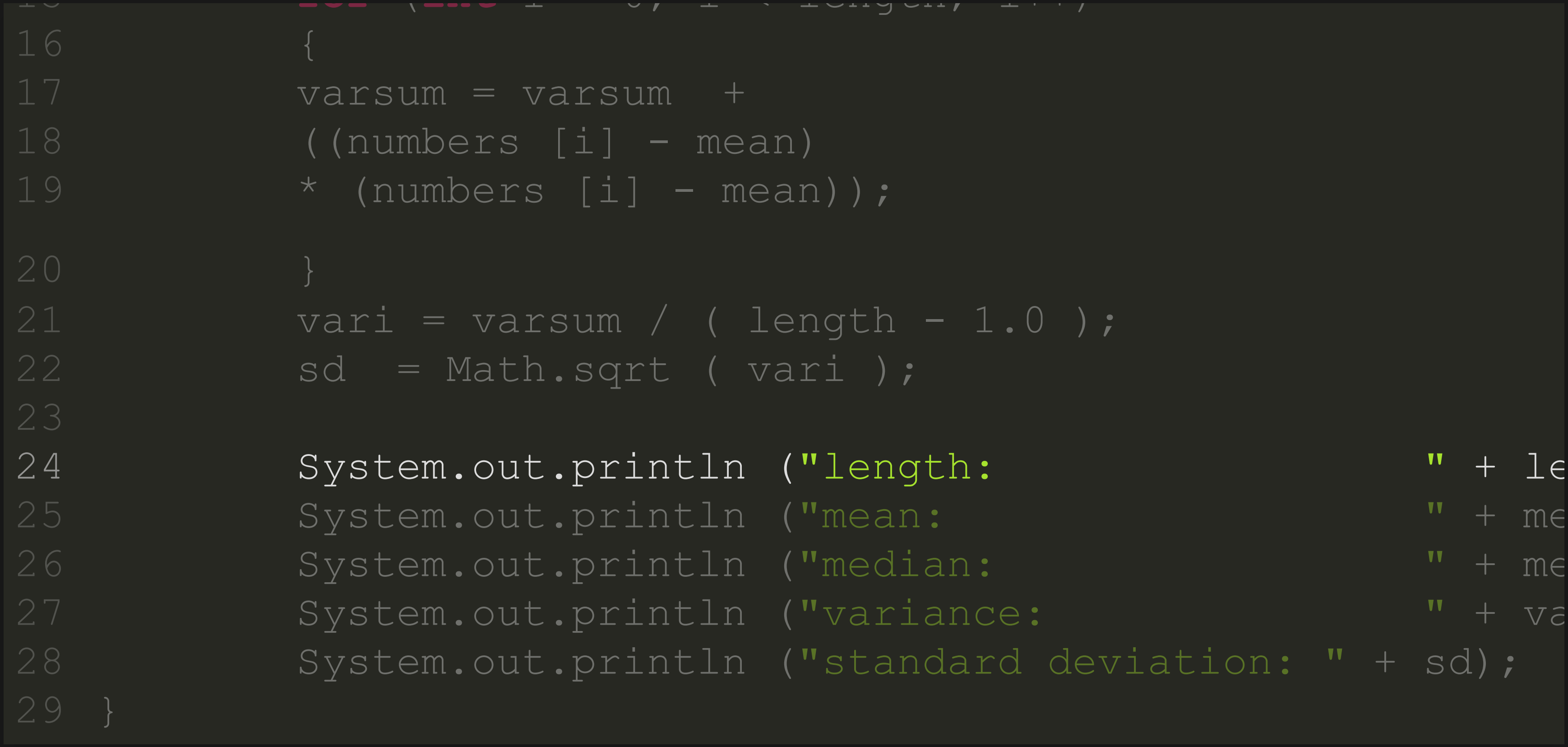
        {
        varsum = varsum  +
        ((numbers [i] - mean)
        * (numbers [i] - mean));

        }
        vari = varsum / ( length - 1.0 );
        sd  = Math.sqrt ( vari );

        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```

USES



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        }
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        sd  = Math.sqrt ( vari );

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        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```
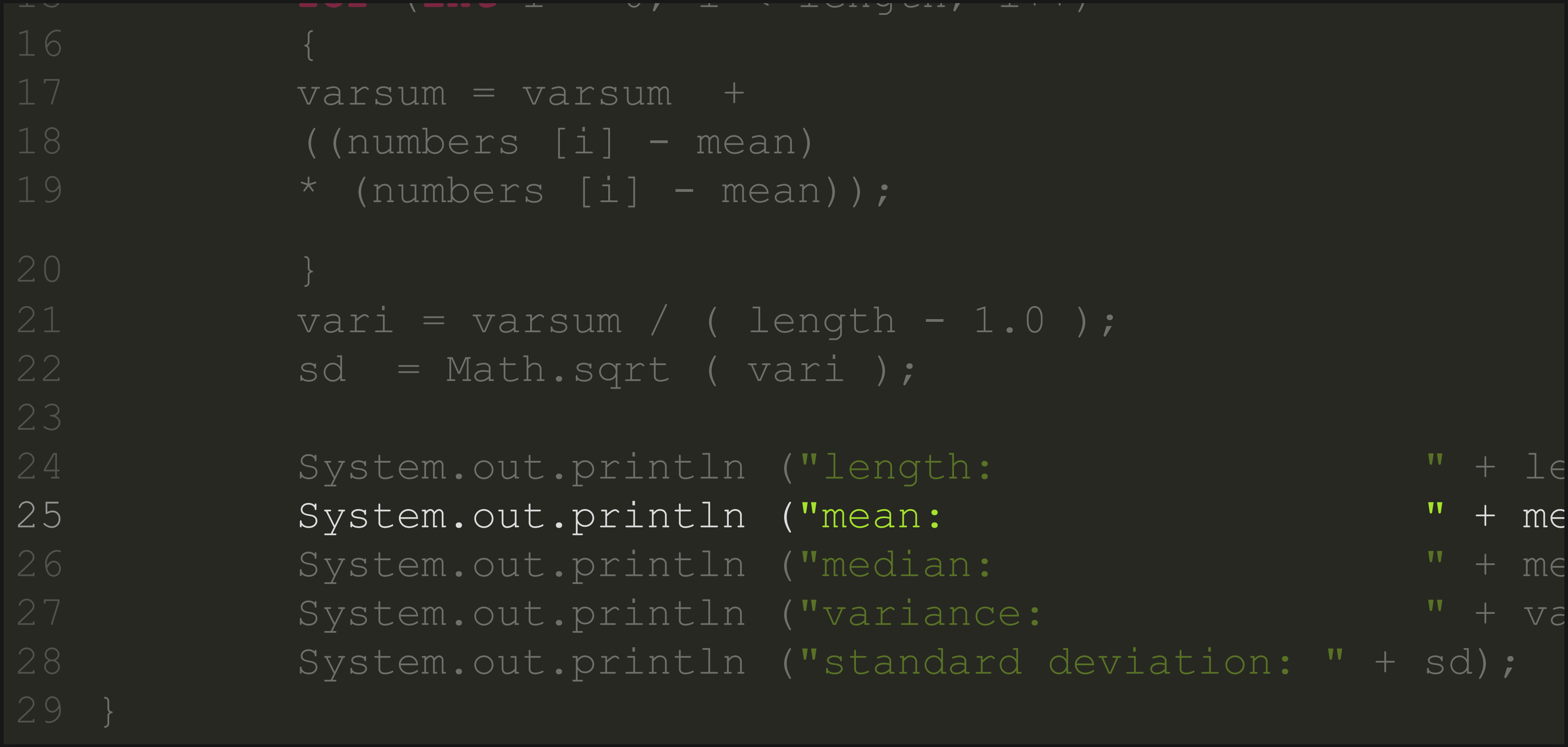

USES



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        for (int i = 0; i < length; i++)
        {
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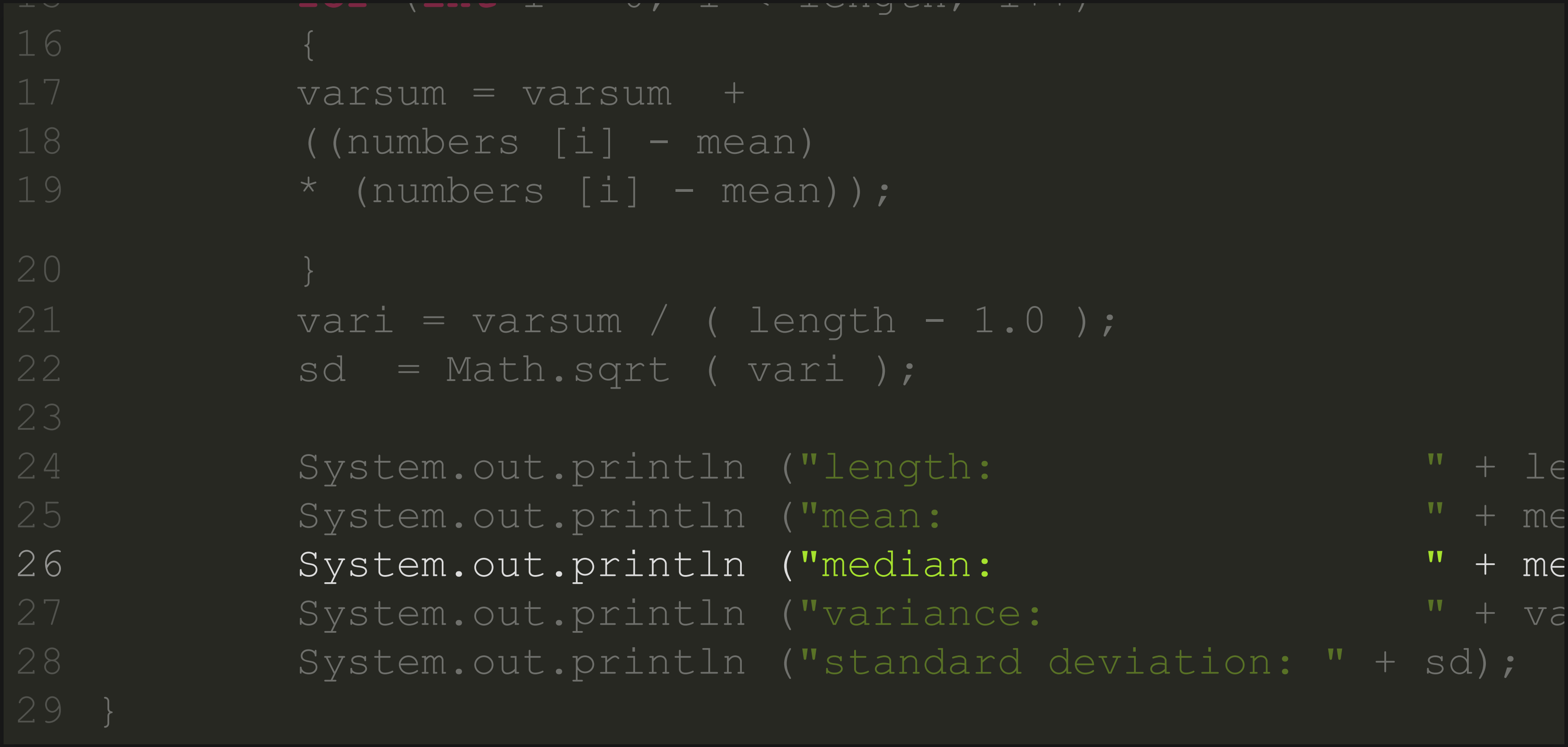
        * (numbers [i] - mean));

        }
        vari = varsum / ( length - 1.0 );
        sd  = Math.sqrt ( vari );

        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```

USES



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        for (int i = 0; i < length; i++)
        {
        varsum = varsum  +
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        }
        vari = varsum / ( length - 1.0 );
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        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```
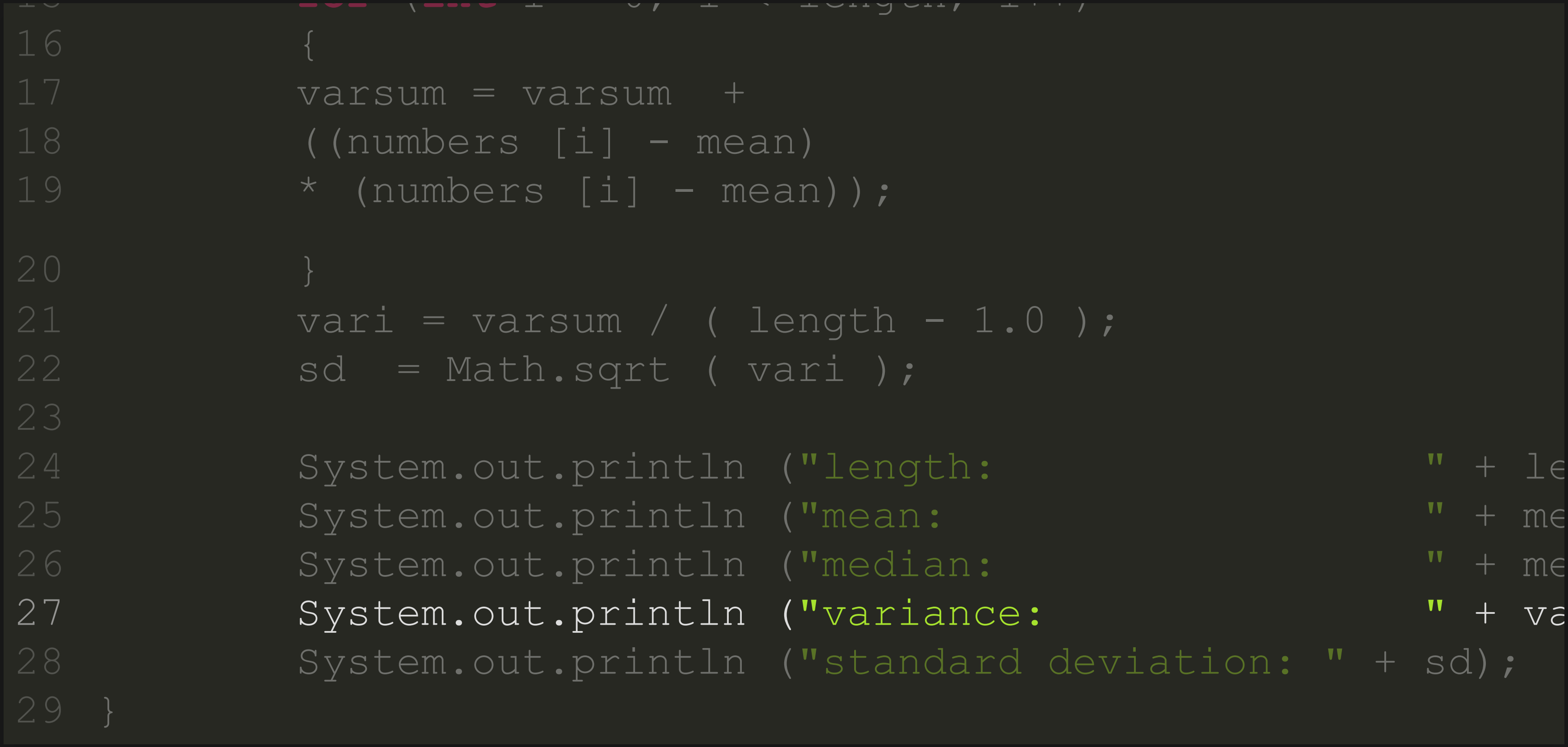

USES



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        }
        vari = varsum / ( length - 1.0 );
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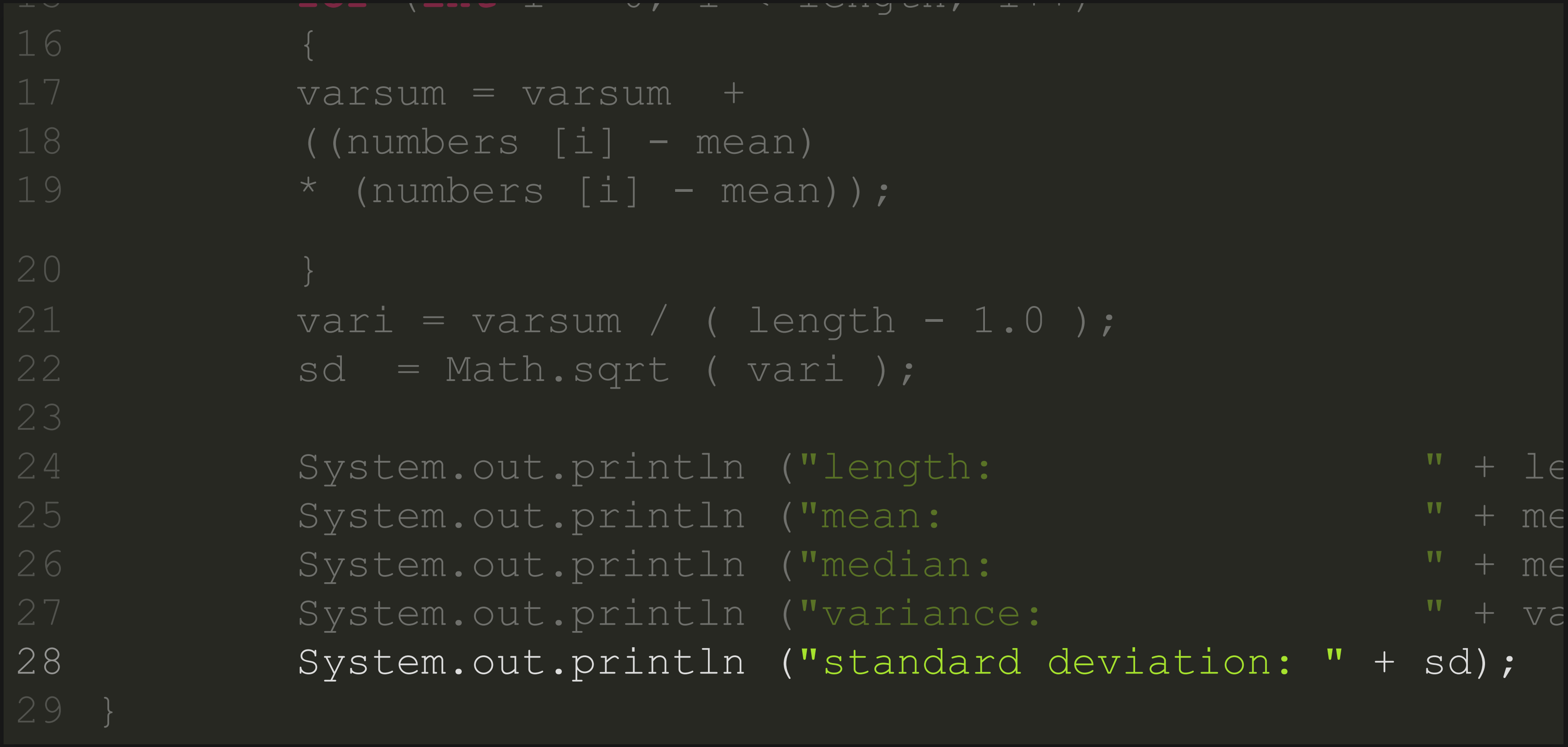
        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```

USES



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        {
        varsum = varsum  +
        ((numbers [i] - mean)
        *  (numbers [i] - mean));

        }
        vari = varsum / ( length - 1.0 );
        sd  = Math.sqrt ( vari );

        System.out.println ("length:                 " + le
        System.out.println ("mean:                   " + me
        System.out.println ("median:                 " + me
        System.out.println ("variance:               " + va
        System.out.println ("standard deviation: " + sd);
}
```
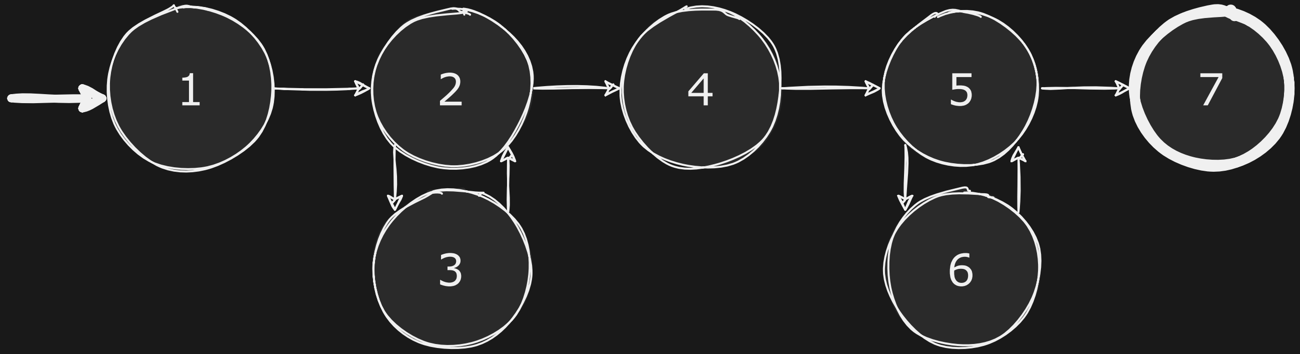



def(1) = { numbers, sum, length, i }
use(2) = { i, length }
def(3) = { sum, i }
use(3) = { sum, numbers, i }
def(4) = { mean, med, varsum, i }
use(4) = { numbers, length, sum }
use(5) = { i, length }
def(6) = { varsum, i }
use(6) = { varsum, numbers, i, mean }
def(7) = {vari, sd }
use(7) = { varsum, length, mean, med, vari, sd }

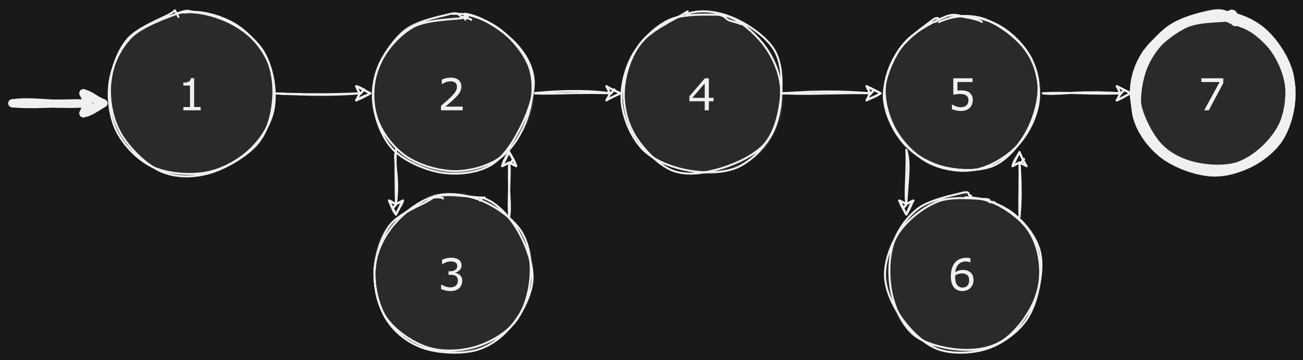
Variable	DU Pairs
numbers	(1 3), (1 4), (1 6)
length	(1 2), (1 4), (1 5)
med	(4 7)
vari	(7 7)
sd	(7 7)
mean	(4 6) (4 7)
sum	(1 3) (1 4) (3 3) (3 4)
varsum	(4 6) (4 7) (6 6) (6 7)
i	(1 2) (1 3) (1 4) (1 5) (1 6) (3 3) (3 2) (3 4) (3 5) (3 6) (6 6) (6 5)

Variable	DU Pairs
numbers	(1 3), (1 4), (1 6)
length	(1 2), (1 4), (1 5)
med	(4 7)
vari	(7 7)
sd	(7 7)
mean	(4 6) (4 7)
sum	(1 3) (1 4) (3 3) (3 4)
varsum	(4 6) (4 7) (6 6) (6 7)
i	(1 2) (1 3) (1 4) (1 5) (1 6) (3 3) (3 2) (3 4) (3 5) (3 6) (6 6) (6 5)

Variable	DU Pairs
numbers	(1 3), (1 4), (1 6)
length	(1 2), (1 4), (1 5)
med	(4 7)
vari	(7 7)
sd	(7 7)
mean	(4 6) (4 7)
sum	(1 3) (1 4) (3 3) (3 4)
varsum	(4 6) (4 7) (6 6) (6 7)
i	(1 2) (1 3) (1 4) (1 5) (1 6) (3 3) (3 2) (3 4) (3 5) (3 6) (6 6) (6 5)

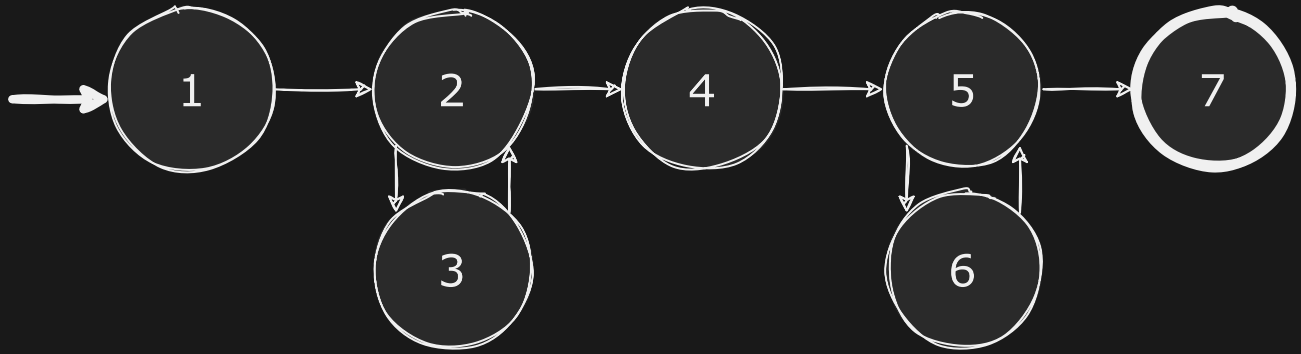
Watch out for scope.

DU PATHS FOR 'NUMBERS'



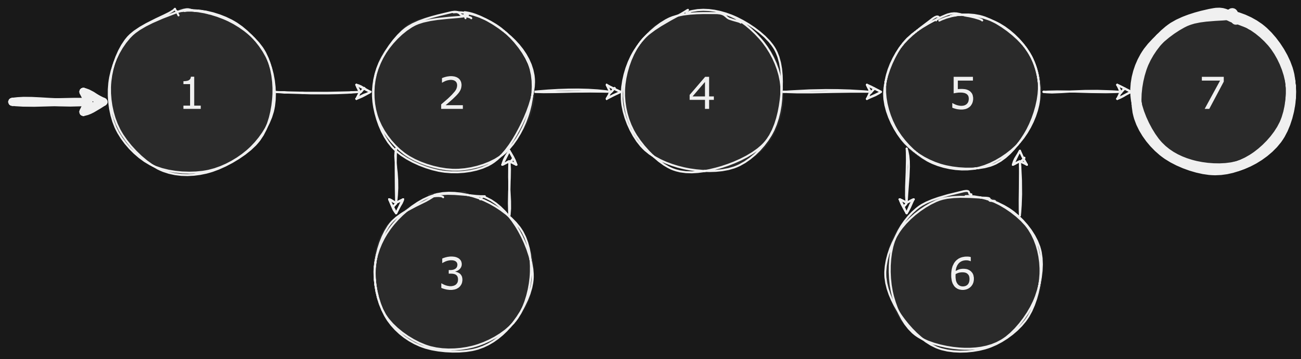
DU Pairs	DU Paths
(1 3)	[1 2 3]
(1 4)	[1 2 4]
(1 6)	[1 2 4 5 6]

DU PATHS FOR 'LENGTH'



DU Pairs	DU Paths
(1 2)	[1 2]
(1 4)	[1 2 4]
(1 5)	[1 2 4 5]

DU PATHS FOR 'LENGTH'



DU Pairs	DU Paths
(1 2)	[1 2]
(1 4)	[1 2 4]
(1 5)	[1 2 4 5]

To tour these paths, we must skip the for loops.

SKIPPING THE FOR LOOPS...

```java
public static void computeStats (int [ ] numbers)
{
        int length = numbers.length;
        double med, vari, sd, mean, sum, varsum;

        sum = 0;
        for (int i = 0; i < length; i++)
        {
                sum += numbers[i];
        }
        med   = numbers [ length / 2 ];
        mean = sum / (double) length;

        varsum = 0;
        for (int i = 0; i < length; i++)
```

SKIPPING THE FOR LOOPS...

```
public static void computeStats (int [ ] numbers)
{
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        varsum = 0;
        for (int i = 0; i < length; i++)
```
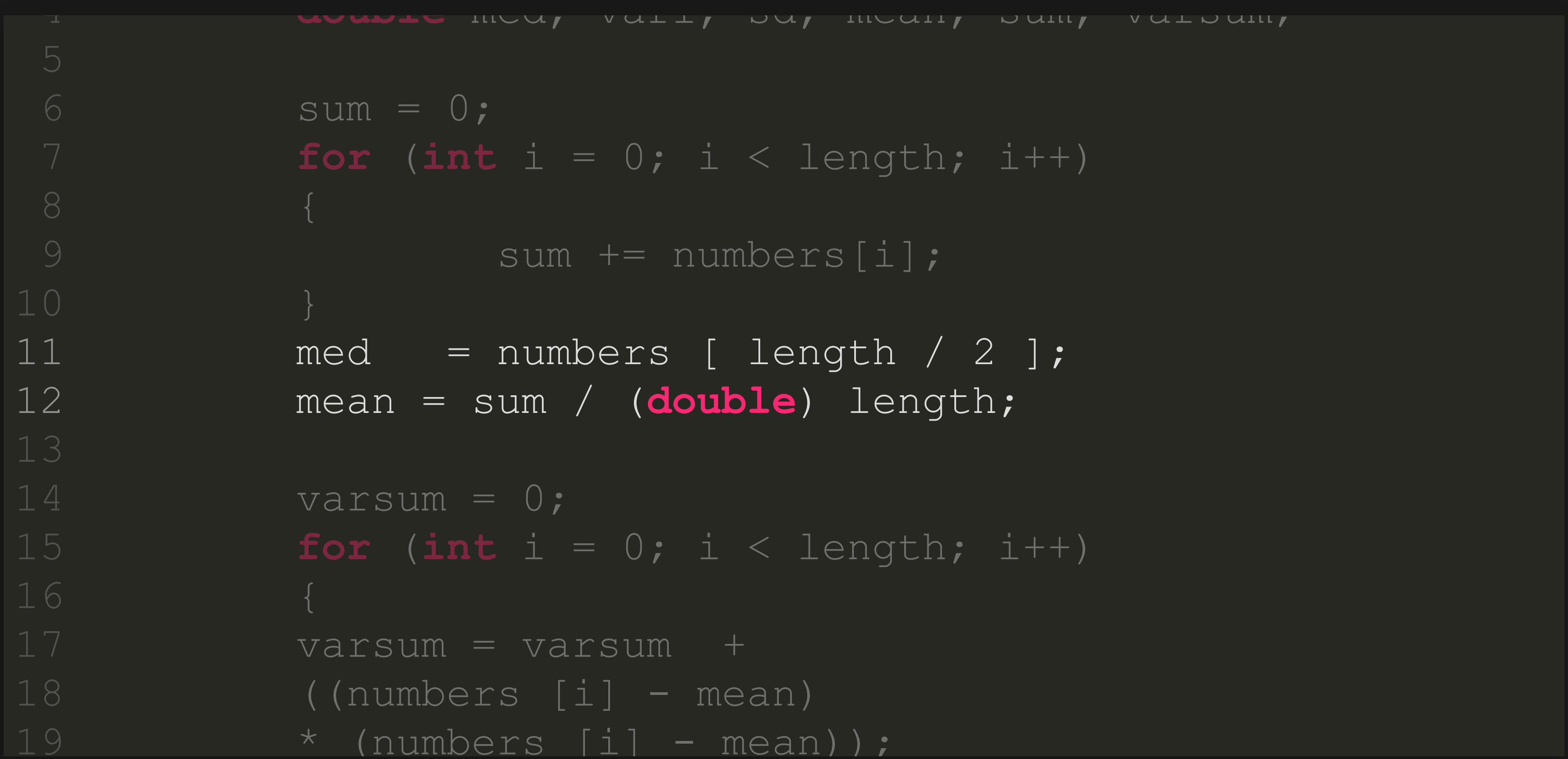

SKIPPING THE FOR LOOPS...



```
double med, vari, sd, mean, sum, varsum;

sum = 0;
for (int i = 0; i < length; i++)
{
        sum += numbers[i];
}
med   = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
*  (numbers [i] - mean));
```

SKIPPING THE FOR LOOPS...

```
sum = 0;
for (int i = 0; i < length; i++)
{
        sum += numbers[i];
}
med    = numbers [ length / 2 ];
mean = sum / (double) length;

varsum = 0;
for (int i = 0; i < length; i++)
{
varsum = varsum  +
((numbers [i] - mean)
*  (numbers [i] - mean));
```

FINITE STATE MACHINES

That's almost it for today, but...

UP NEXT...

That concludes graph coverage! Next week:

- Logic
- Lots of logic.