# IA {Test} AI

## A new Battlefield!

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# AI-based Testing

# Continuous Integration Cycle

## Software testing timeline

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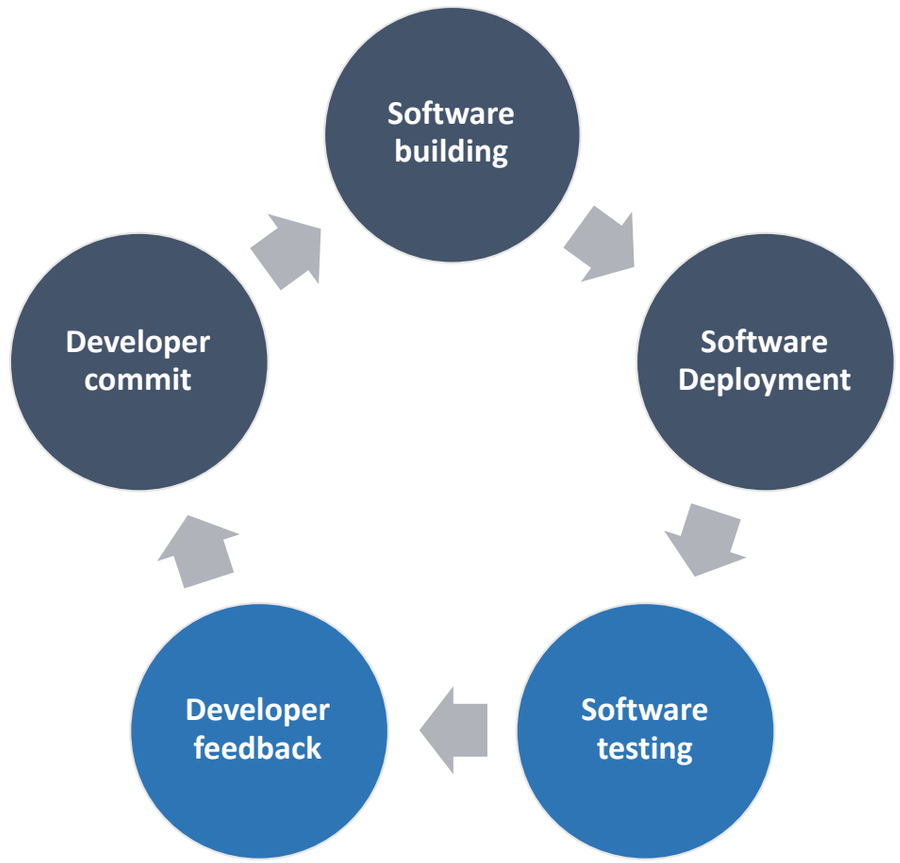
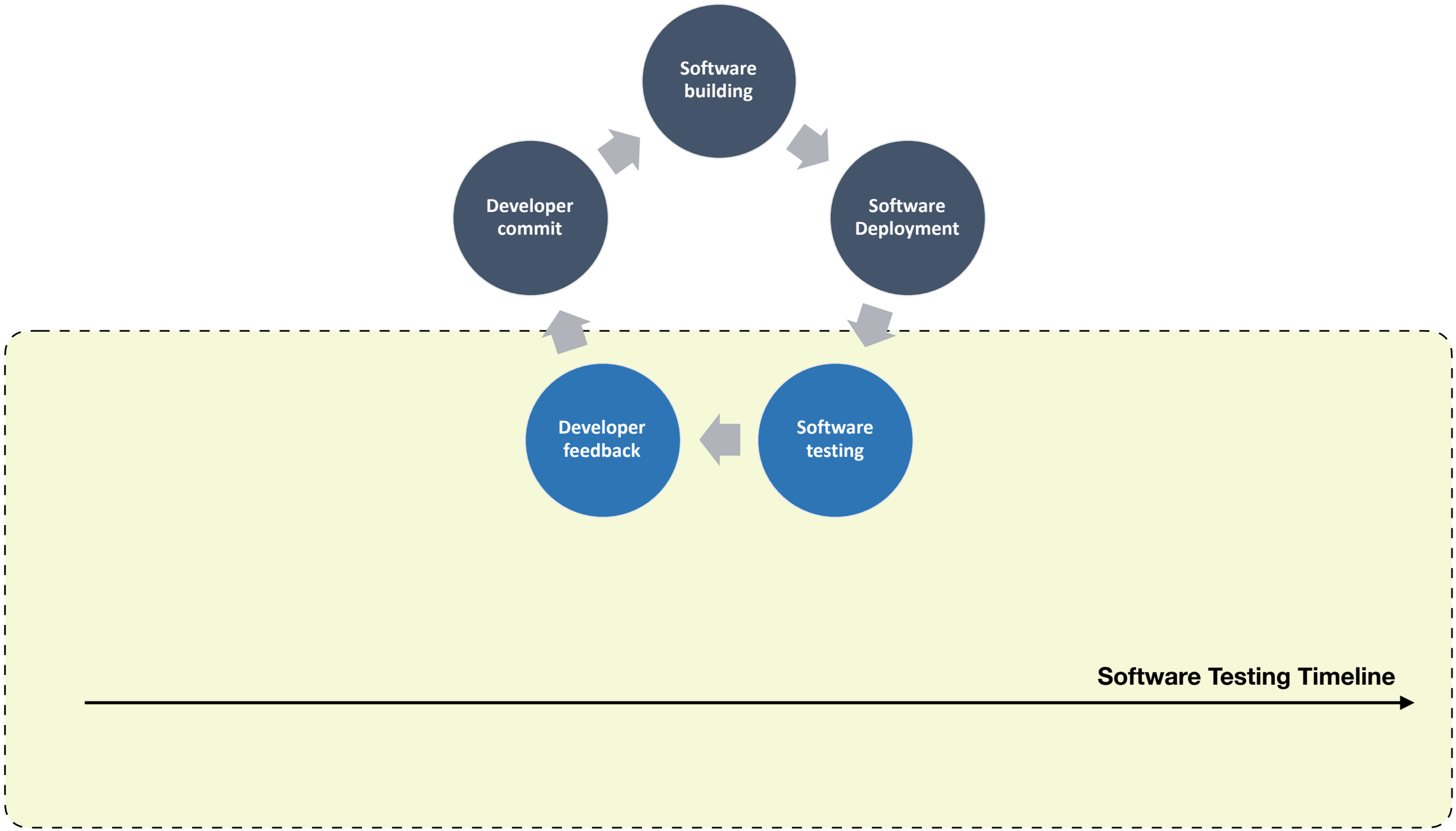


# Continuous Integration Cycle

## Software testing timeline



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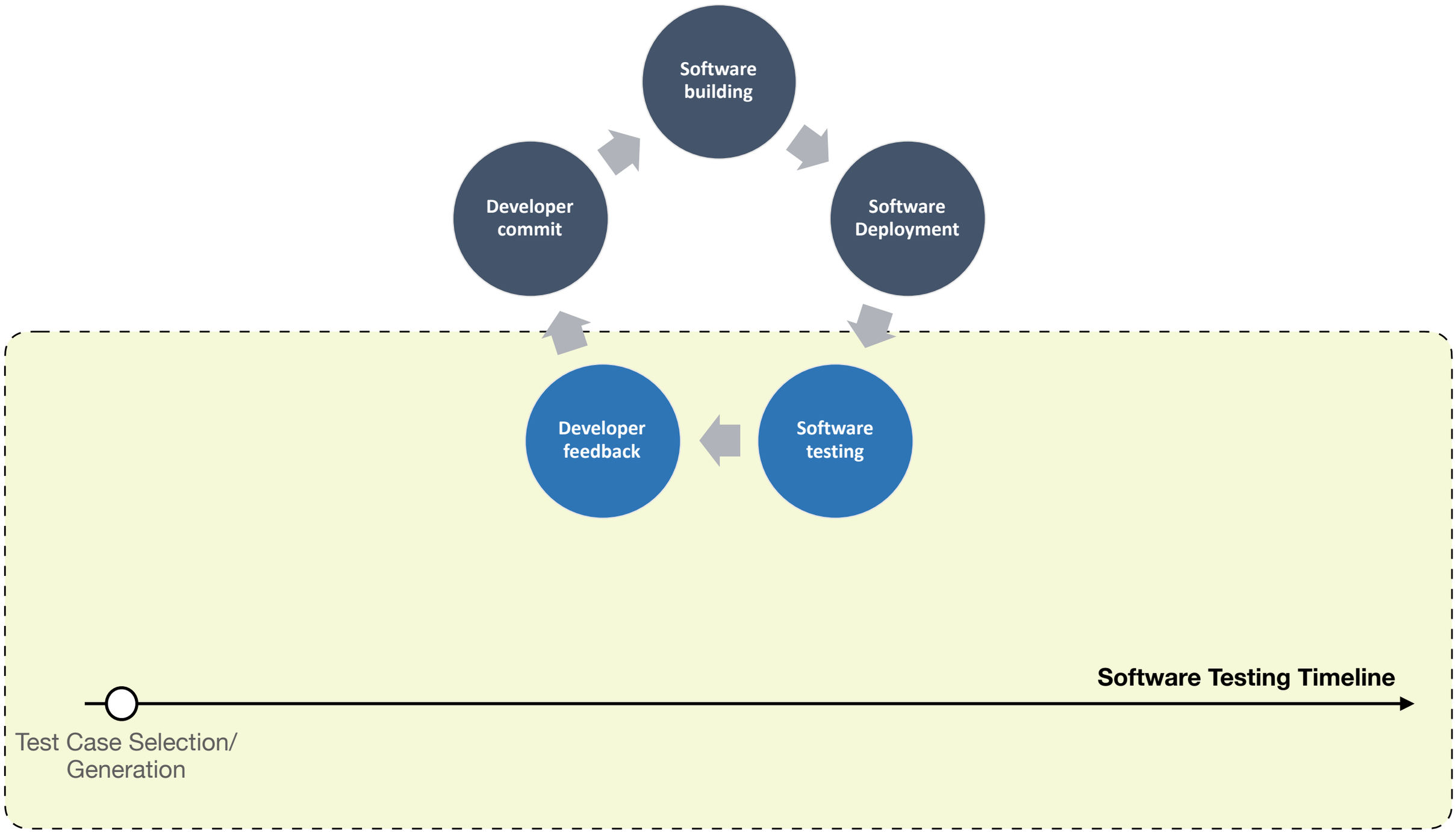

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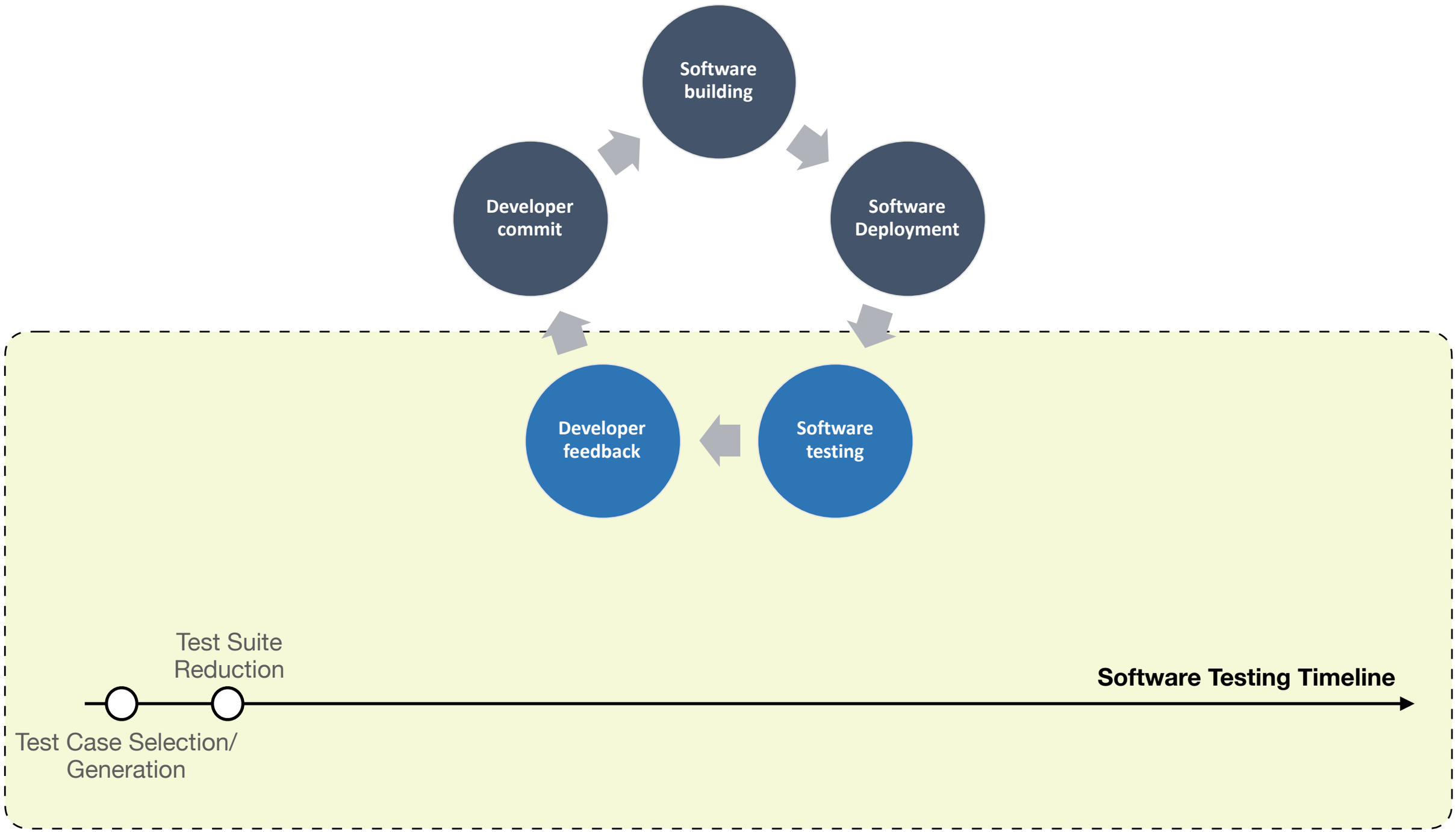

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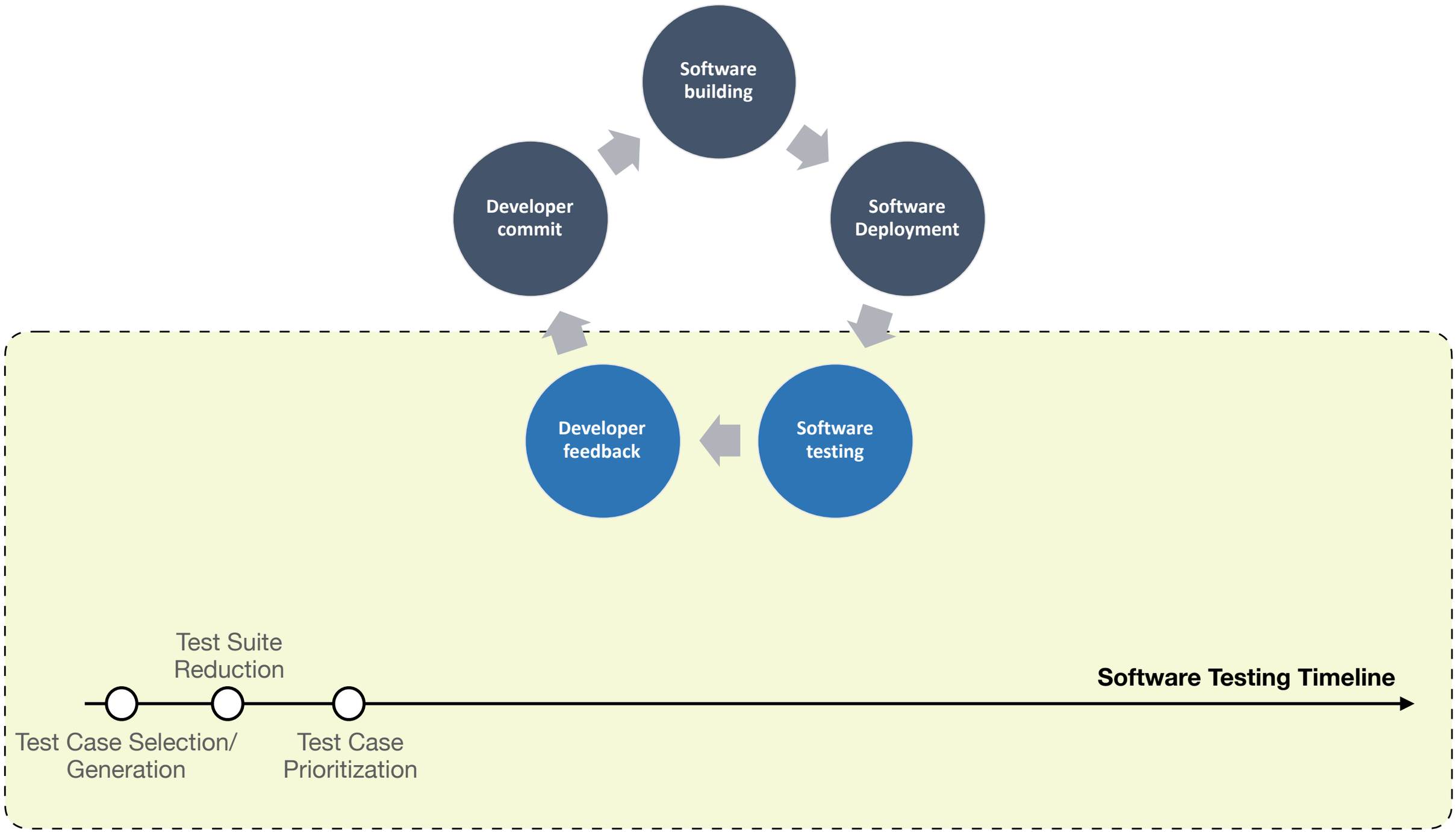

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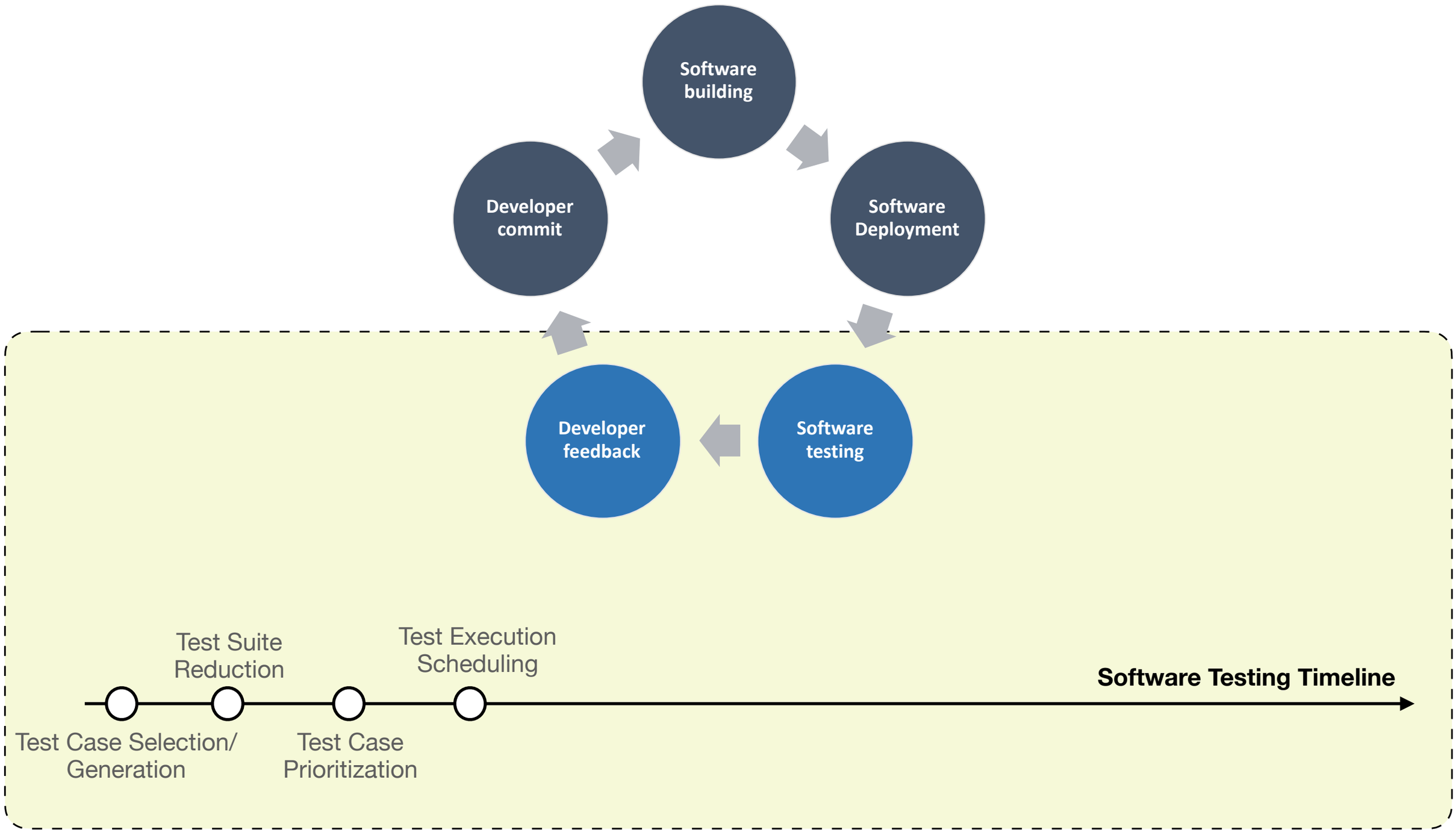

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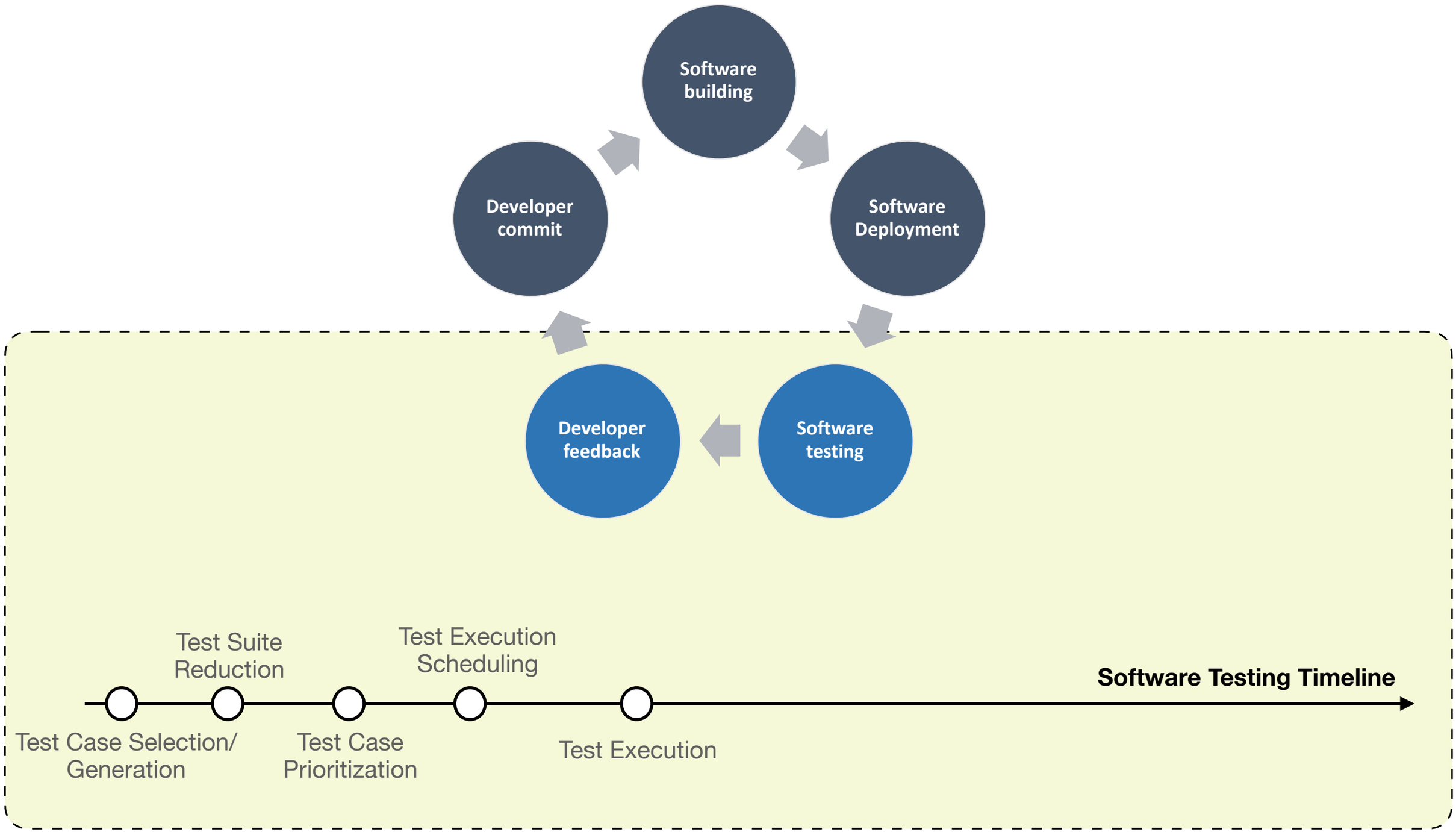


# AI-based Testing (AI4VV)

## Testing Tasks

- Automatic test case generation
- Test suite reduction
- Test case prioritization
- Test execution scheduling
- …

# AI-based Testing (AI4VV)

## Automatic Test Case Generation

$P$

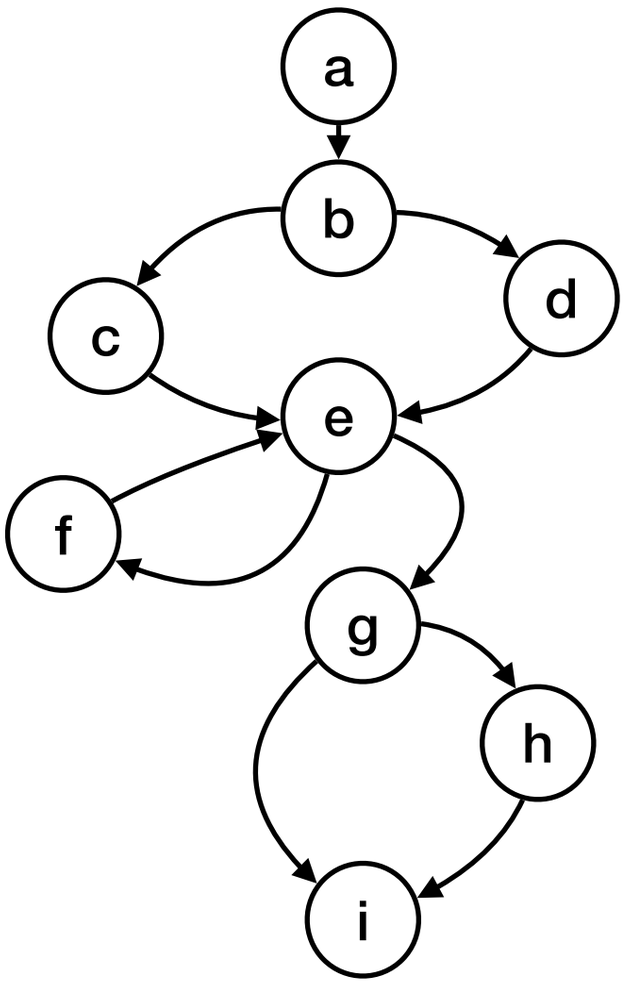
```
double power(int x, int y) {

        int i, p;
        i = 0;
        double z = 1;
        if (x < 0)
            p = -x;
        else
            p = x;
        while (i < p) {
            z = z * x;
            i = i + 1;
        }
        if (y < 0)
            x = 1 / x;
        return x;
    }
```

$P_{SSA}$

```
double power(int x_1, int y_1) {

        int i_1, p_1;
        i_1 = 0;
        double z_1 = 1;
        if (x_1 < 0)
            p_1 = -x_1;
        else
            p_2 = x_1;
        p_3= phi(p_1,p_2);
        while (i_1 < p_3) {
            z_2 = z_1 * x_1;
            i_2 = i_1 + 1;
        }
        z_3= phi(z_1,z_2);
        i_3=phi(i_1,i_2);
        if (y_1 < 0)
            x_2 = 1 / x_1;
       x_3 = phi(x_1,x_2);
        return x_3;
    }
```



# Automatic Test Case Generation

## Exercise

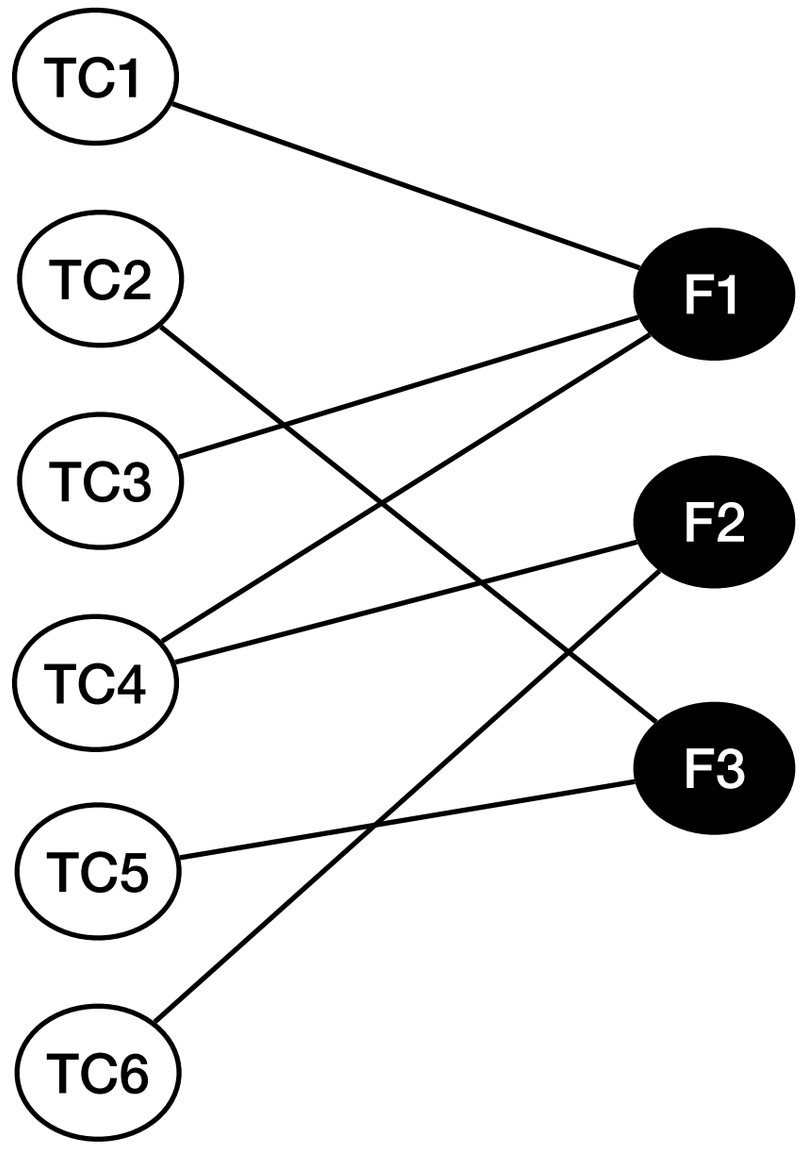
```
public int trityp(int a, int b, int c) {

1:      int type;
2:      if (a <= 0 || b <= 0 || c <= 0)
3:          type = 1;
4:      if (a >= (b + c) || c >= (b + a) || b >= (a + c))
5:          type = 2;
6:      if (a == b && b == c)
7:          type = 3;
8:      else if (((a * a) + (b * b)) == (c * c) || ((a * a) + (c * c)) == (b * b)
                                                || ((c * c) + (b * b)) == (a * a))
9:          type = 4;
10:     else if (a != b && b != c && c != a)
11:         type = 5;
12:     else if ((a == b && b != c) || (a != b && c == a) || (c == b && c != a))
13:         type = 6;
14:     return type;
    }
```

**Q: Give the corresponding FCG + the SSA program version + the 6 constraint networks to cover the 6 statements (3, 5, 7, 9, 11, 13)**

# AI-based Testing (AI4VV)

## Test Suite Reduction



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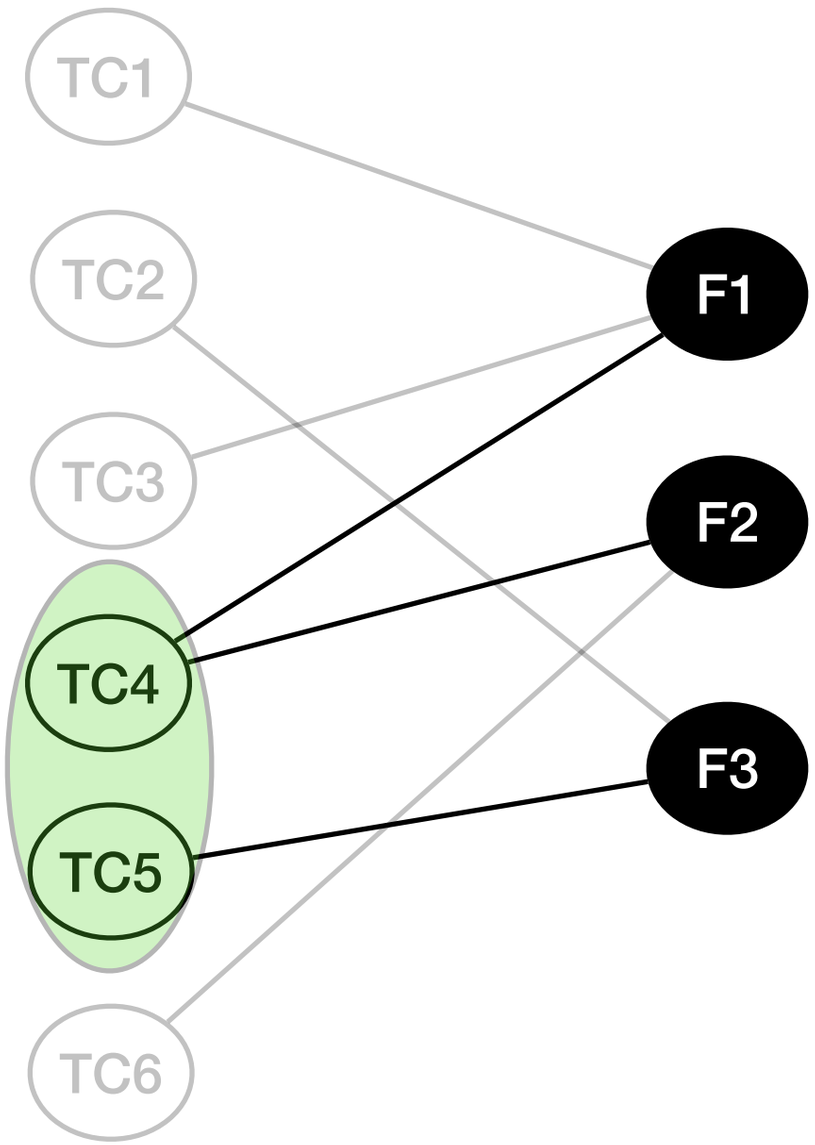

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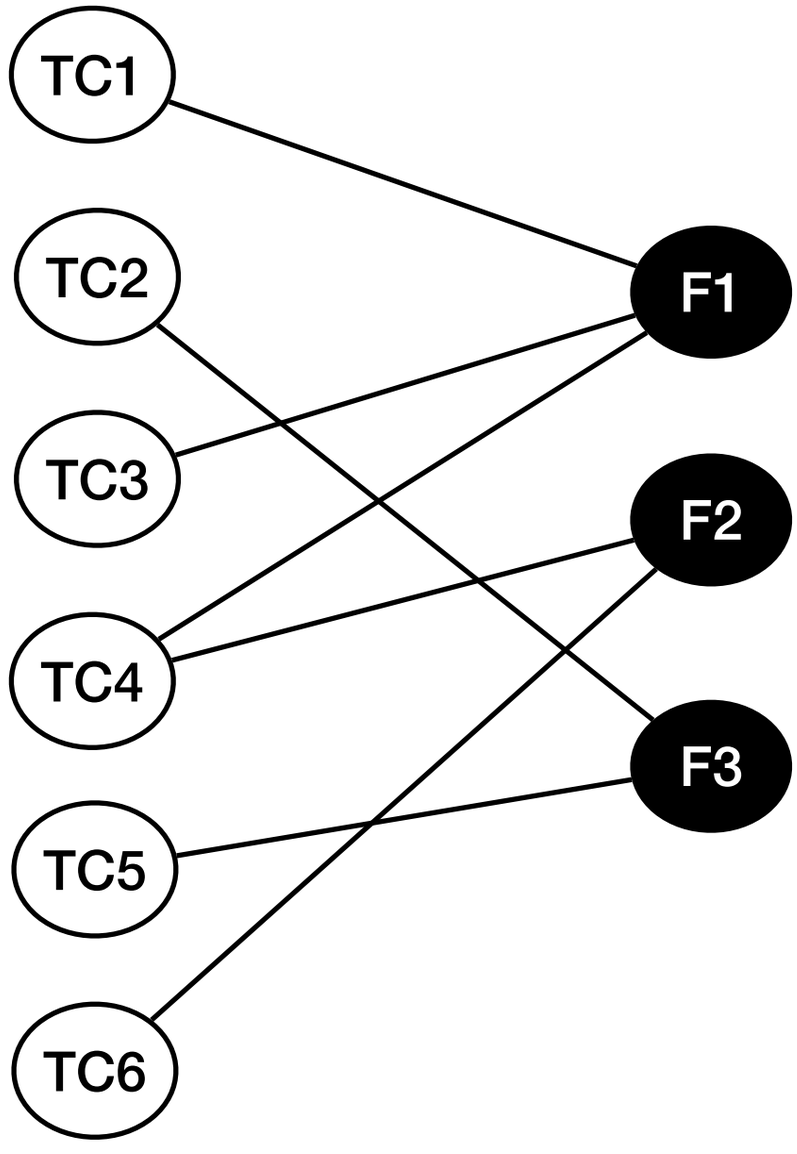
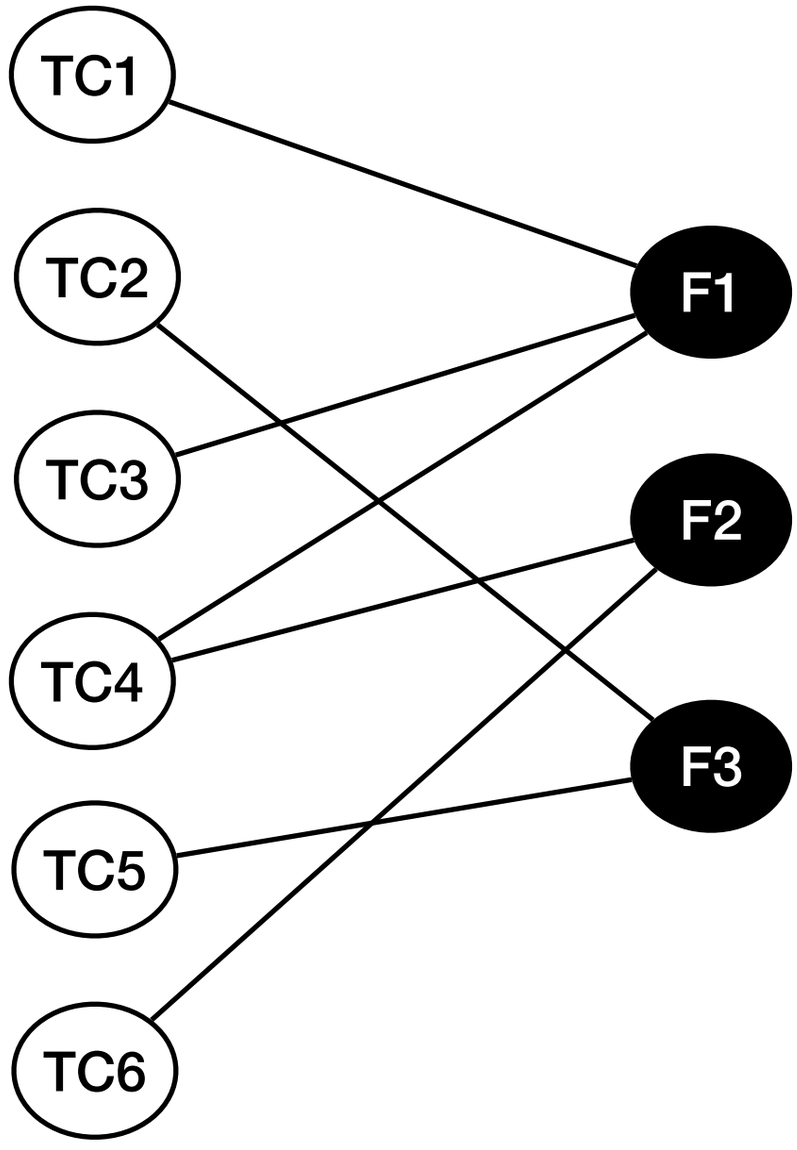


# AI-based Testing (AI4VV)

## Test Suite Reduction

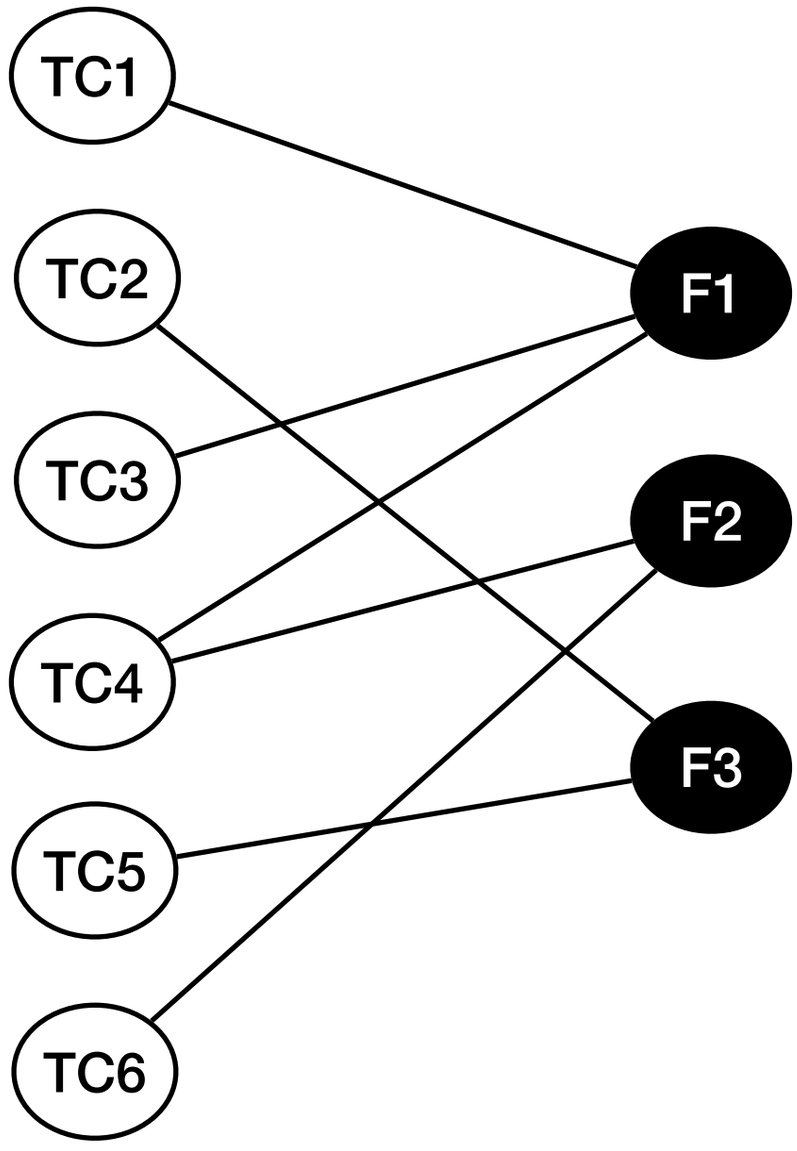
- Vertex Cover Problem in a bipartite graph



# AI-based Testing (AI4VV)

## Test Suite Reduction

- Vertex Cover Problem in a bipartite graph
- NP-Hard problem



# AI-based Testing (AI4VV)

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- Vertex Cover Problem in a bipartite graph
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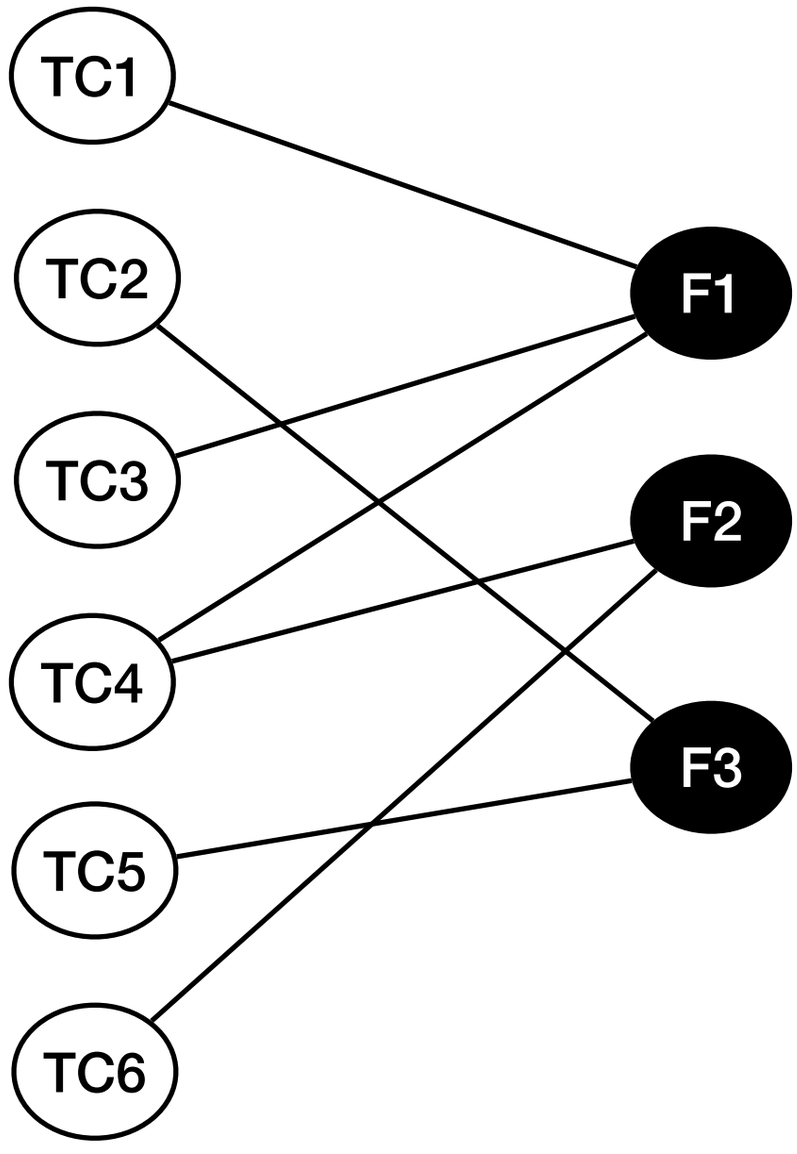
- Existing approaches:



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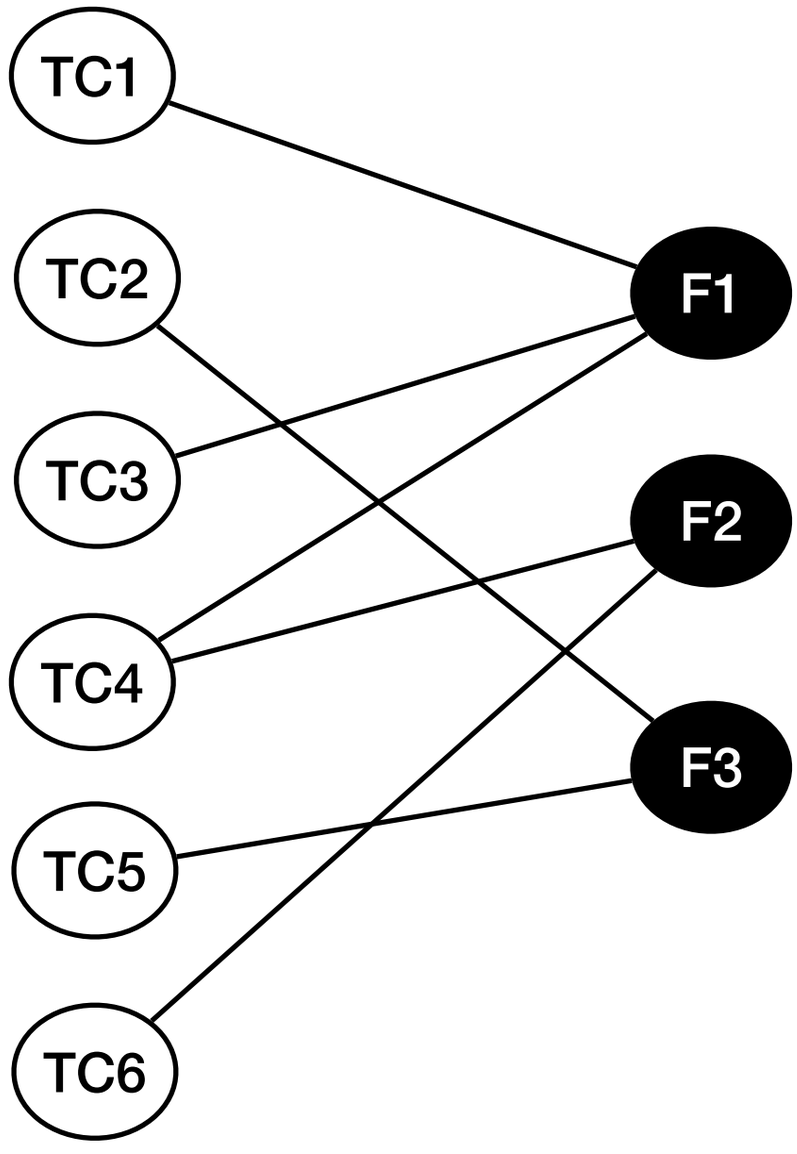

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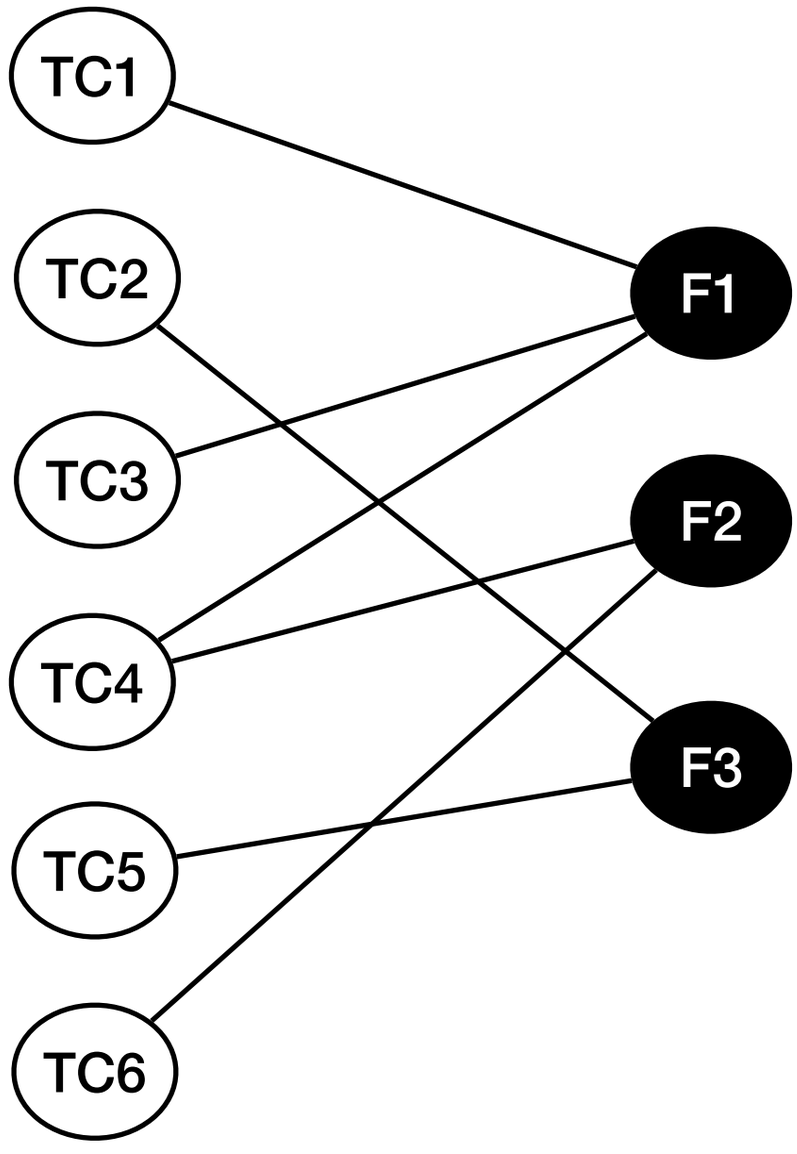
Minimize $\sum_{i \in [1,6]} x_i$

Subject to:

- $x_1 + x_3 + x_4 \geq 1$
- $x_4 + x_6 \geq 1$
- $x_2 + x_5 \geq 1$



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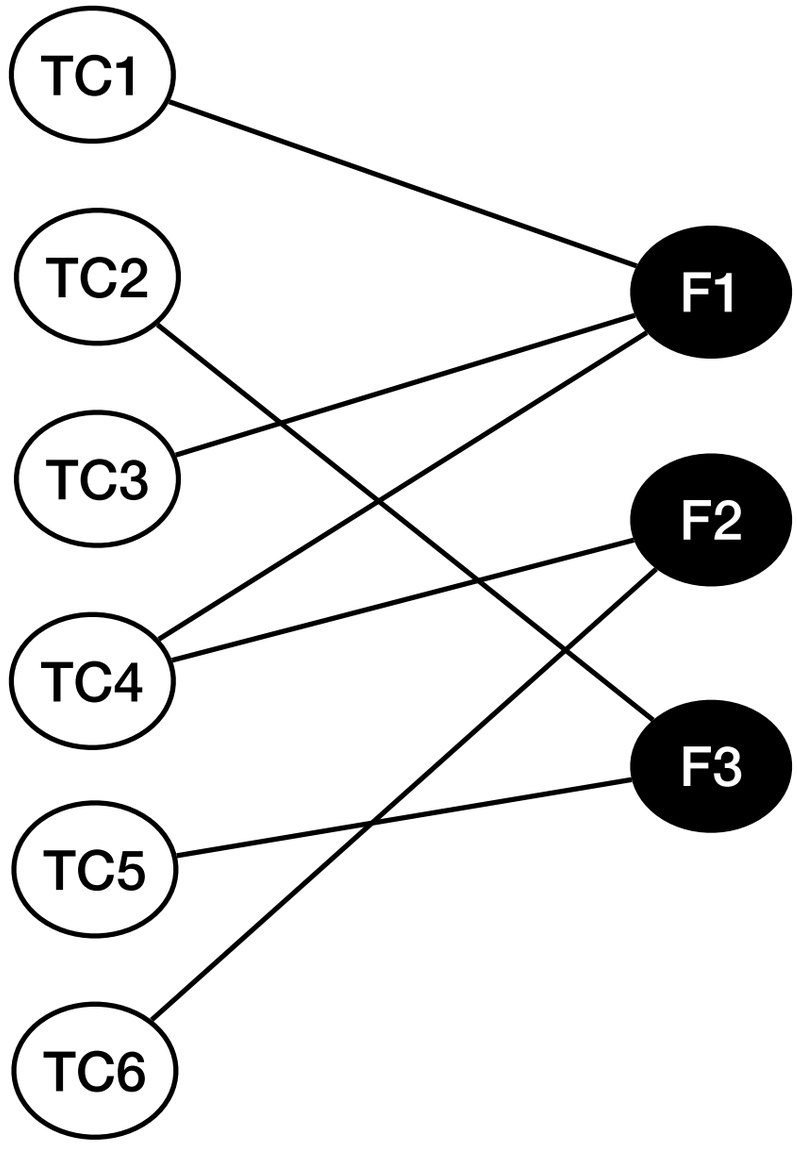

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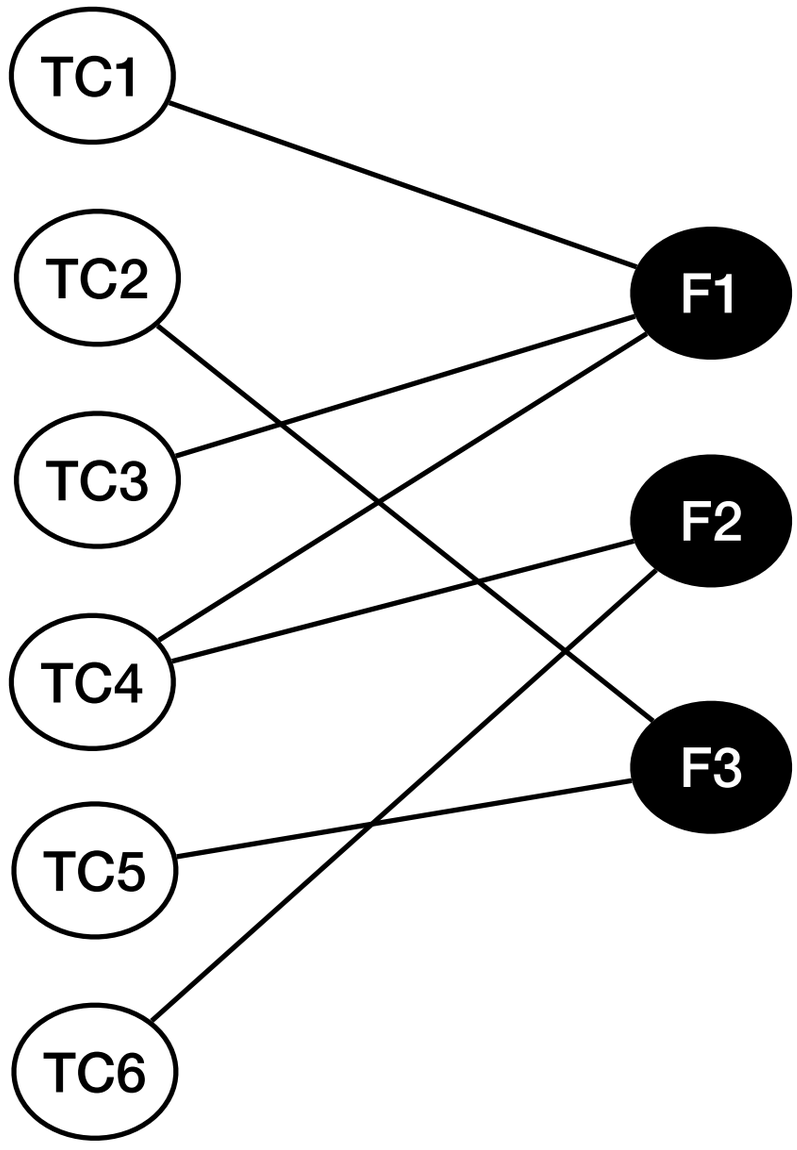
```
F={F1, F2, F3}; S=∅
while(S=∅)
   Pick TCi covering max(F\S)
   S= S ∪ cover(TCi)
Return S
```



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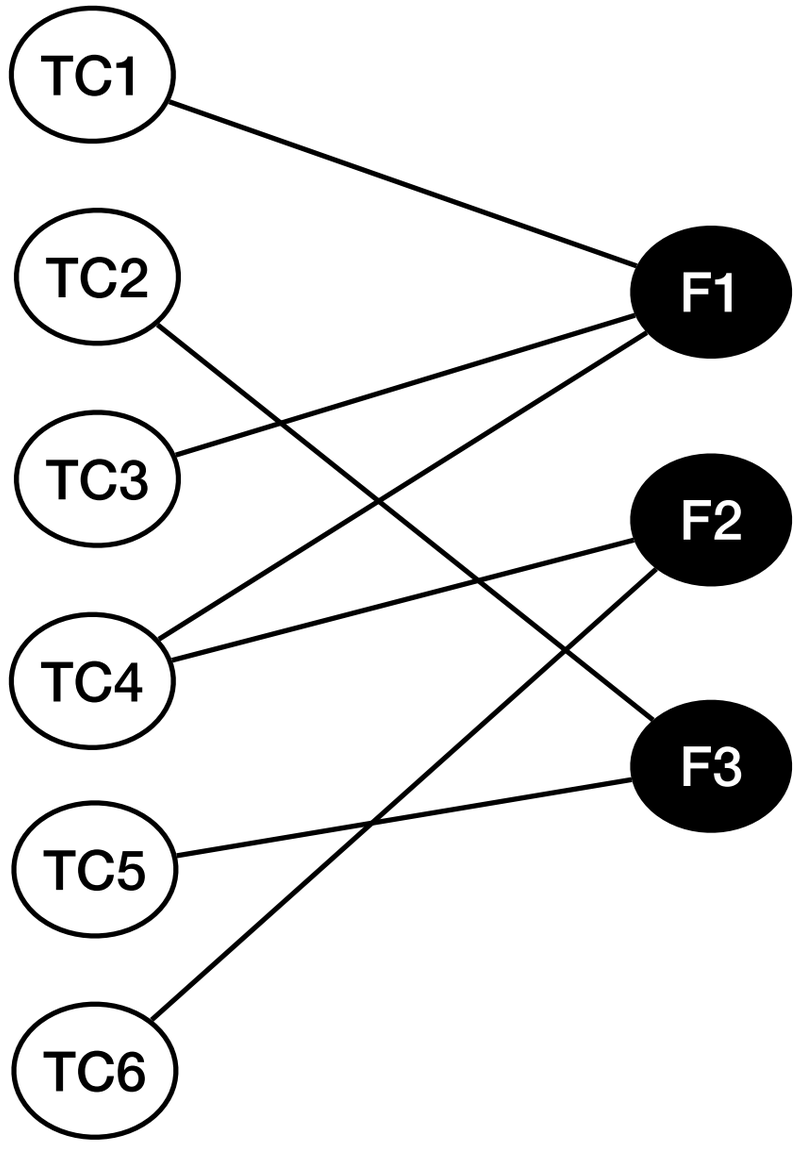
  - Constraint Programming [Gotlieb et al. ISSTA 2014, AI Maganize 2016,…]



# AI-based Testing (AI4VV)

## Test Suite Reduction

- Vertex Cover Problem in a bipartite graph
- NP-Hard problem
- Existing ap
- ILP app

  Abreu QSI
- Approxi

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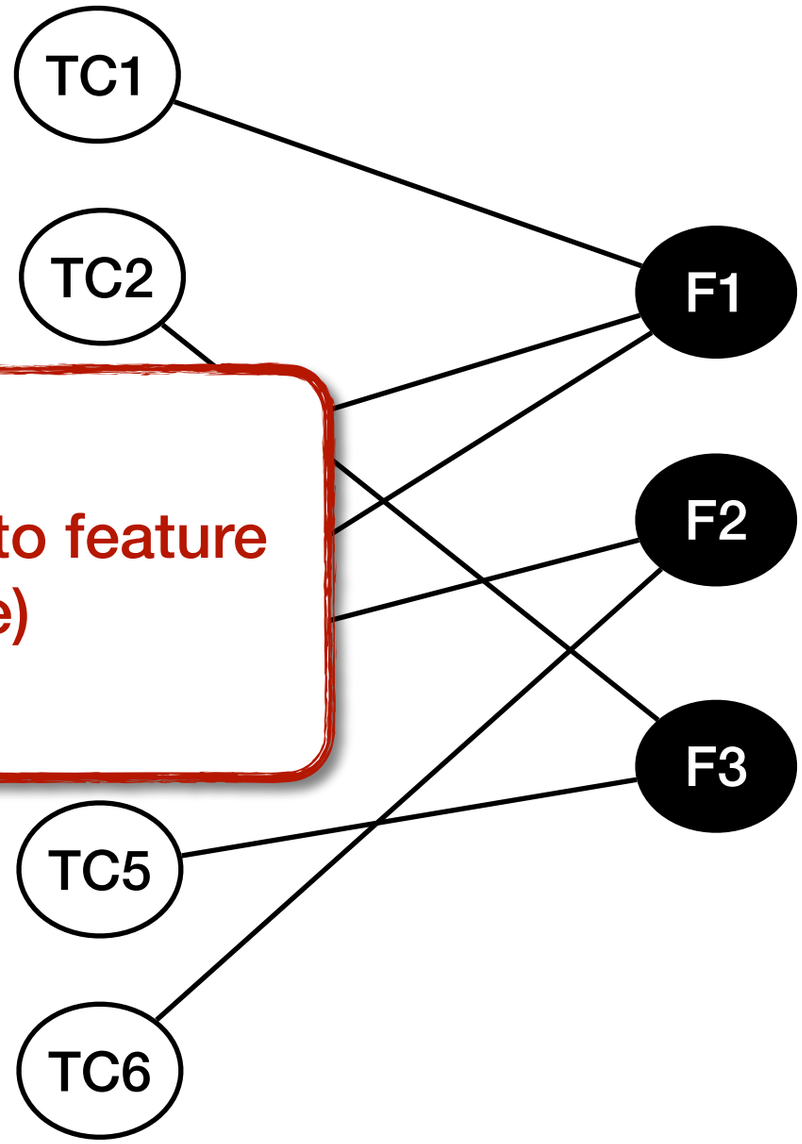
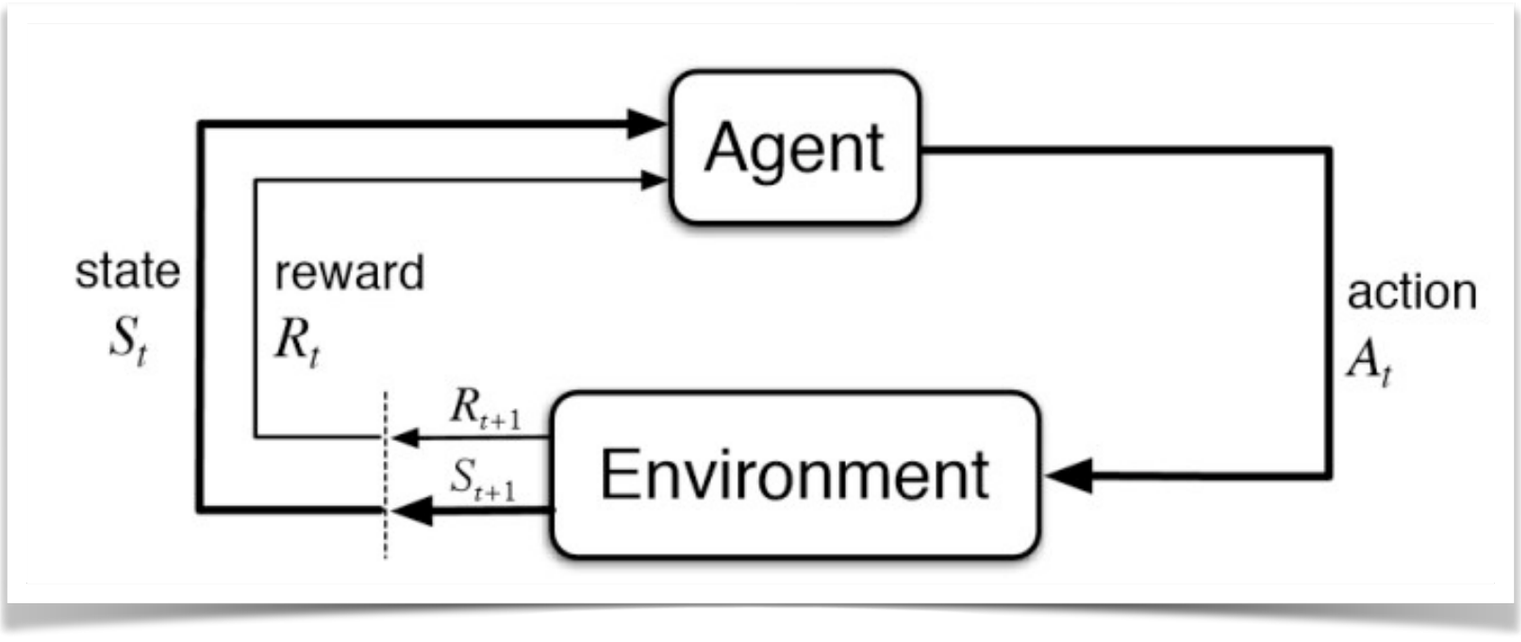
**Other criteria to minimize in addition to feature coverage (e.g. execution time)**



# AI-based Testing (AI4VV)

## Test Case Prioritization

- Adaptive Testing:
  - focus on the more error-prone parts of the system
  - Execution environment (available devices, limited time and ressources, previous feedback from continuous integration cycle)
-



# AI-based Testing (AI4VV)

## Test Execution Scheduling

- Test cases with distinct characteristics using limited ressources
- Limited number of test cases that can be executed simultaneously
- Test cases sharing same ressources cannot be executed simultaneously
- Each test case must be executed!
- Timespan to minimize (the overall schedule duration)

# Testing AI-based systems

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## Crucial and Challenging Task

- Widespread application of AI
- AI-based systems are vulnerable
- Vulnerability of AI-based systems can lead to fatal failures
- The verification/validation of AI-based systems still involve too much human labour
- AI-based system behaviours evolve with changing contexts
- Testing of AI-based systems faces a number of challenges compared to testing of traditional systems

# Testing AI-based systems

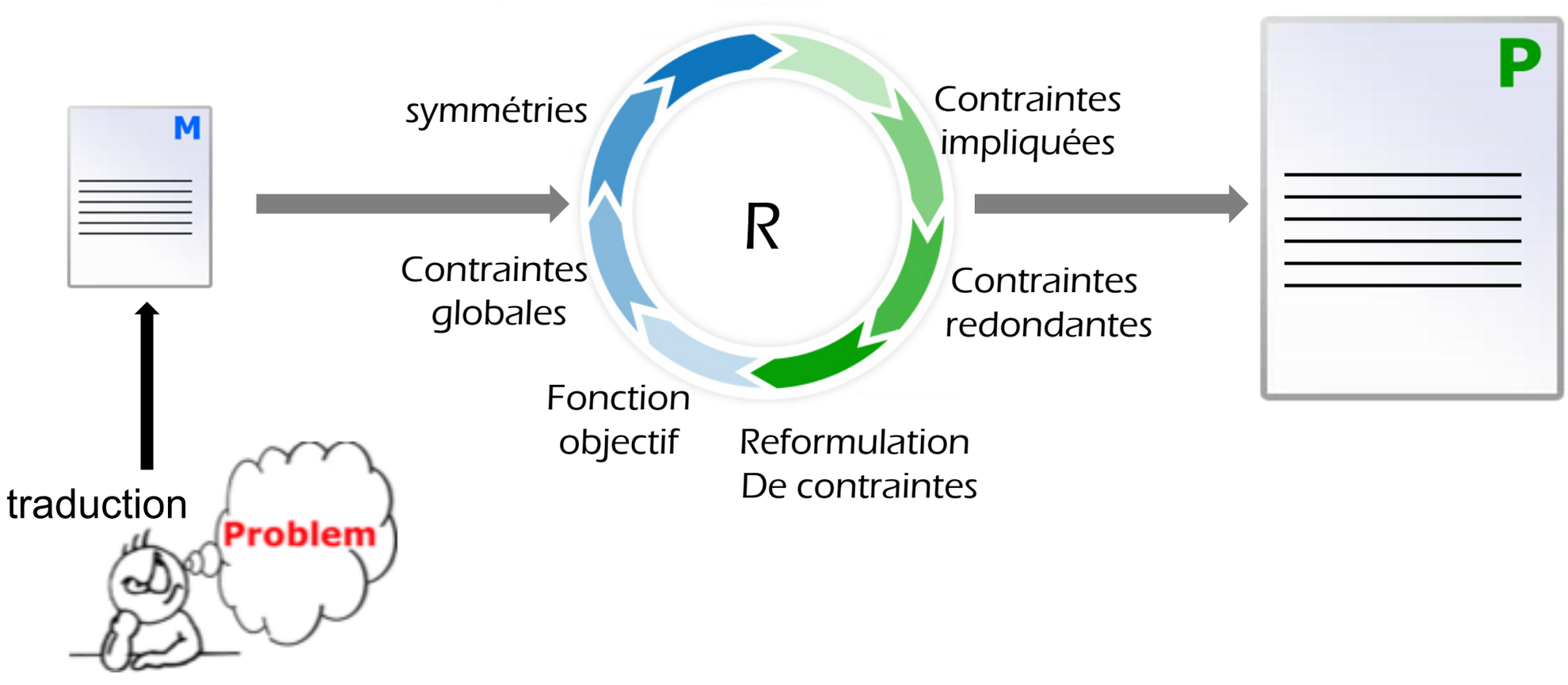
## « Testing AI »

- AI point of vue:
  - Testing AI is performed to estimate its accuracy, and improve its performance
  - During model creation, using validation and test datasets, to evaluate the model fit on the training dataset

- Software testing community
  - Testing has a wider scope, aiming to evaluate the system behaviour against a range of quality attributes (functional/non-functional requirements)

# Testing AI-based systems

## CPTEST [Lazaar et al, 2012]



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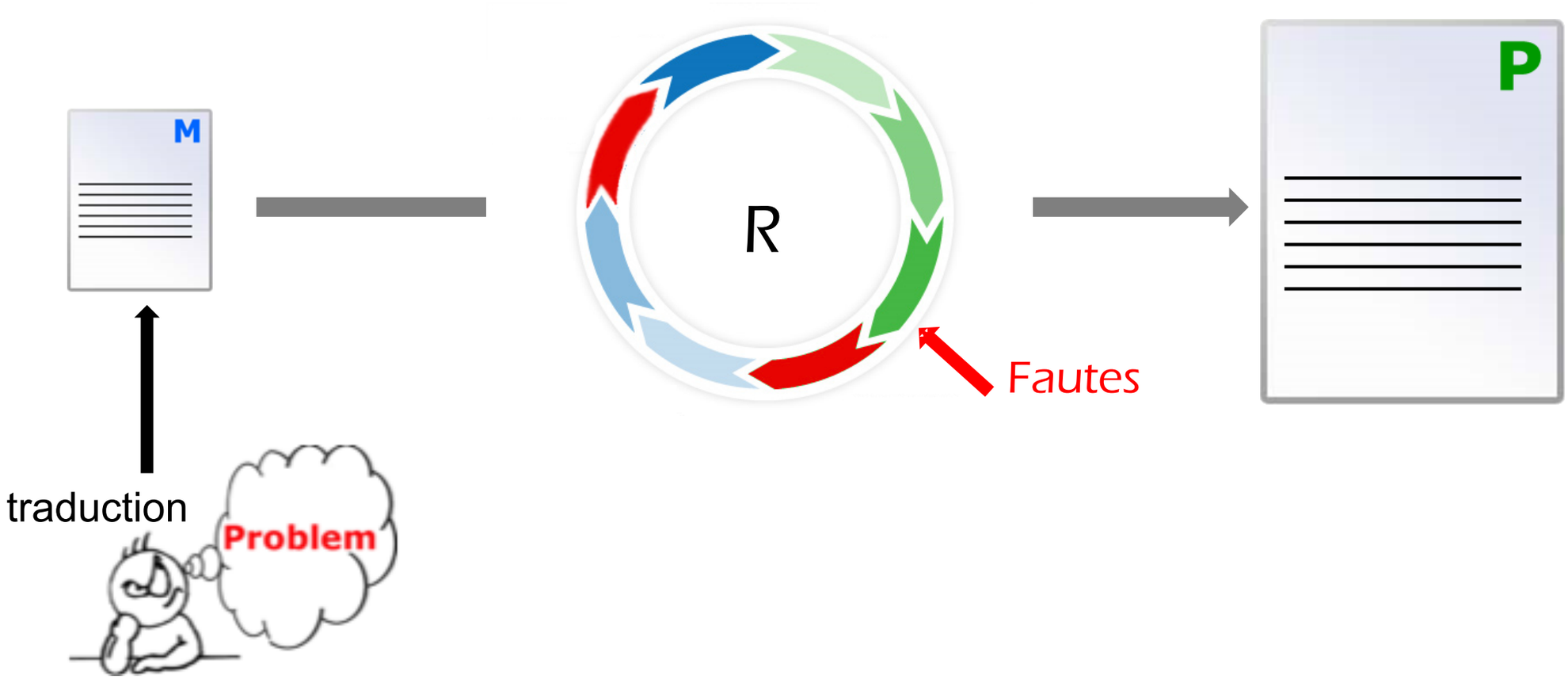

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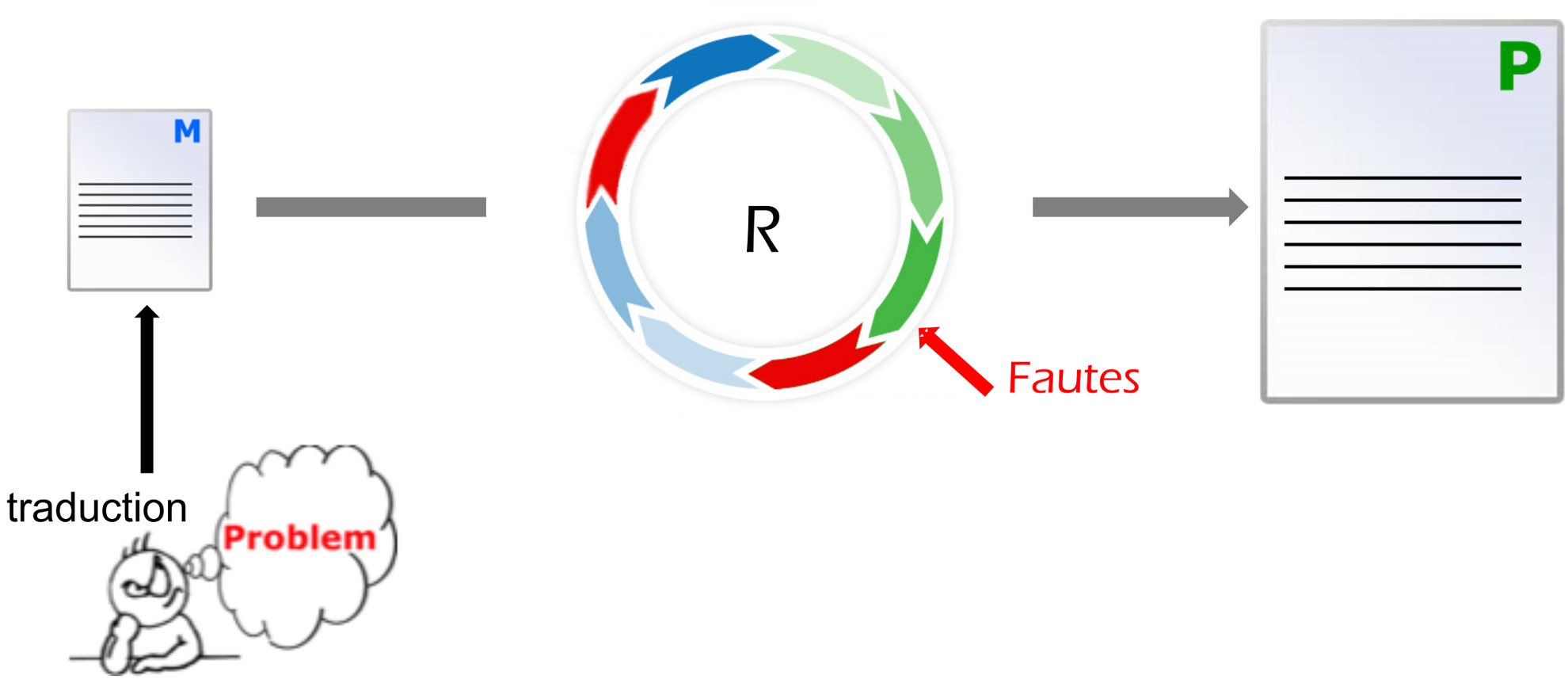
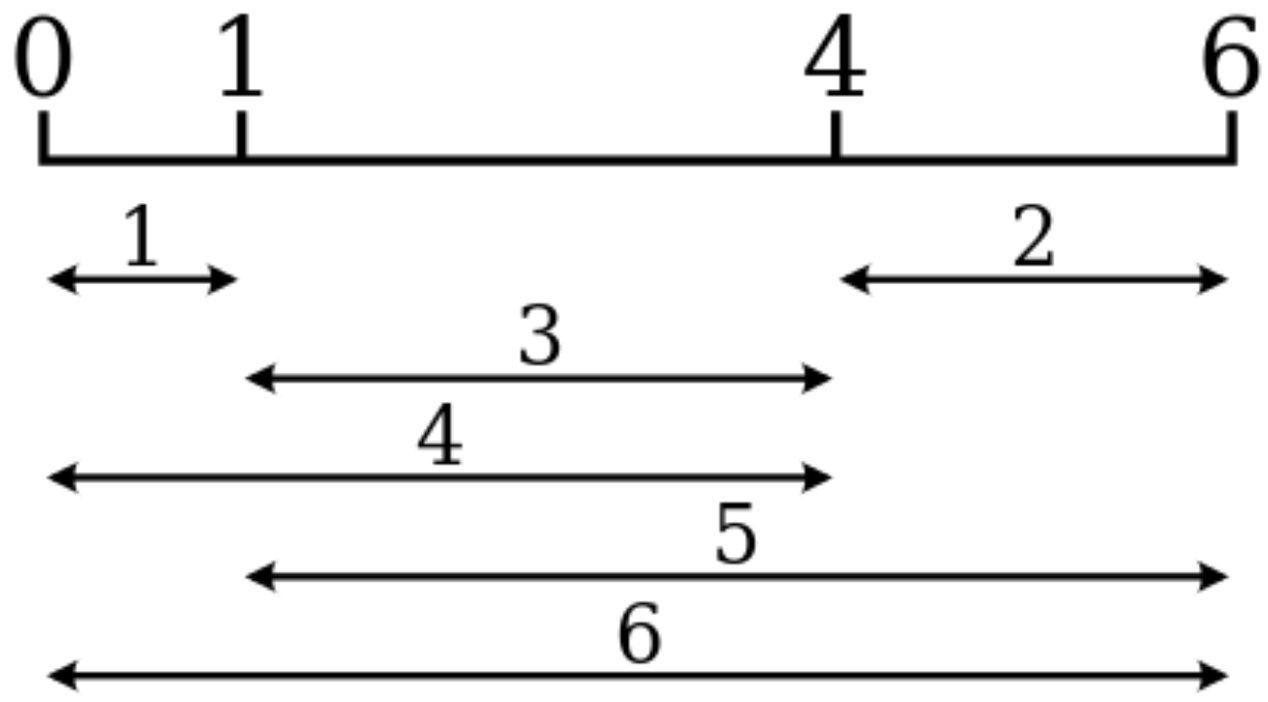


# CPTEST

## Example (Golomb ruler)

- a **Golomb ruler** is a set of marks at integer positions along a ruler such that no two pairs of marks are the same distance apart.



# CPTEST

## Example (Golomb ruler)

(A)

```
using CP;

int m=...;

dvar int x[1..m] in 0..m *m;

minimize x[m];

subject to{

c1: forall(i in 1..m - 1)
     x[i]  < x[i+1] ;

c2: forall(ordered i,j in 1..m)
    forall(ordered k, l in 1..m:
                    (i!=k||j!=l))
     !((x[j]-x[i]) == (x[l]-x[k]));
}
```

(B)

```
using CP;

int m=...;
int nbDist= m*(m-1)div 2;


dvar int x[1..m] in 0..m*m;
dvar int d[1..nbDist];

minimize d[m-1];

subject to {

cc1: forall (i in 1..m-1)
      x[i] < x[i+1];

cc2: forall(ordered i,j in 1..m)
      d[(nbDist-((m-i+1)*(m-i)div 2))+(j-i)]
                                  == x[j]-x[i];
//cc2': forall(ordered i,j in 1..nbDist div m)
//      d[nbDist-(j-i)] == x[j]-x[i];
```

faute

```
cc3: x[1]==0;

cc4: x[2] <= d[nbDist];

cc5: x[m] >= nbDist;

cc6: allDifferent(d);

cc7: forall(ordered i,j in 2..m, k in 1..m*m)
      x[i]==x[i-1]+k => x[j]!=x[j-1]+k;
}
```

# Testing AI-based systems

## CPTEST [Lazaar et al, 2012]

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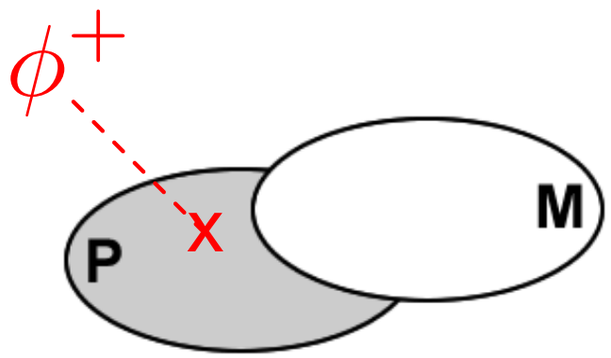

# Testing AI-based systems

## CPTEST

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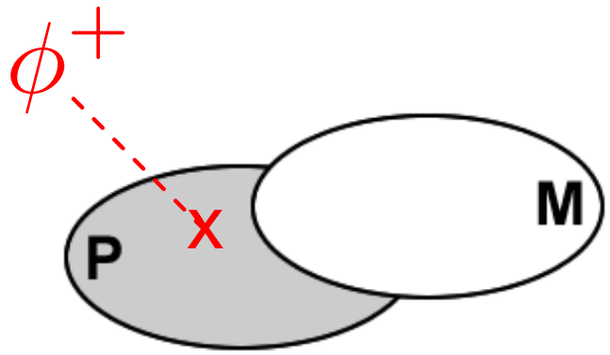


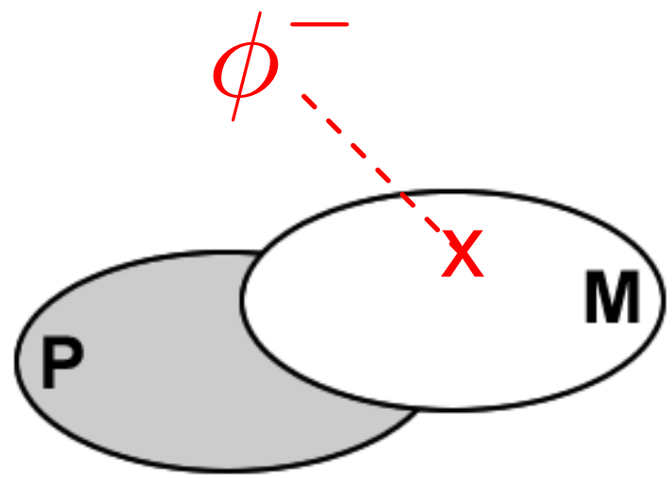

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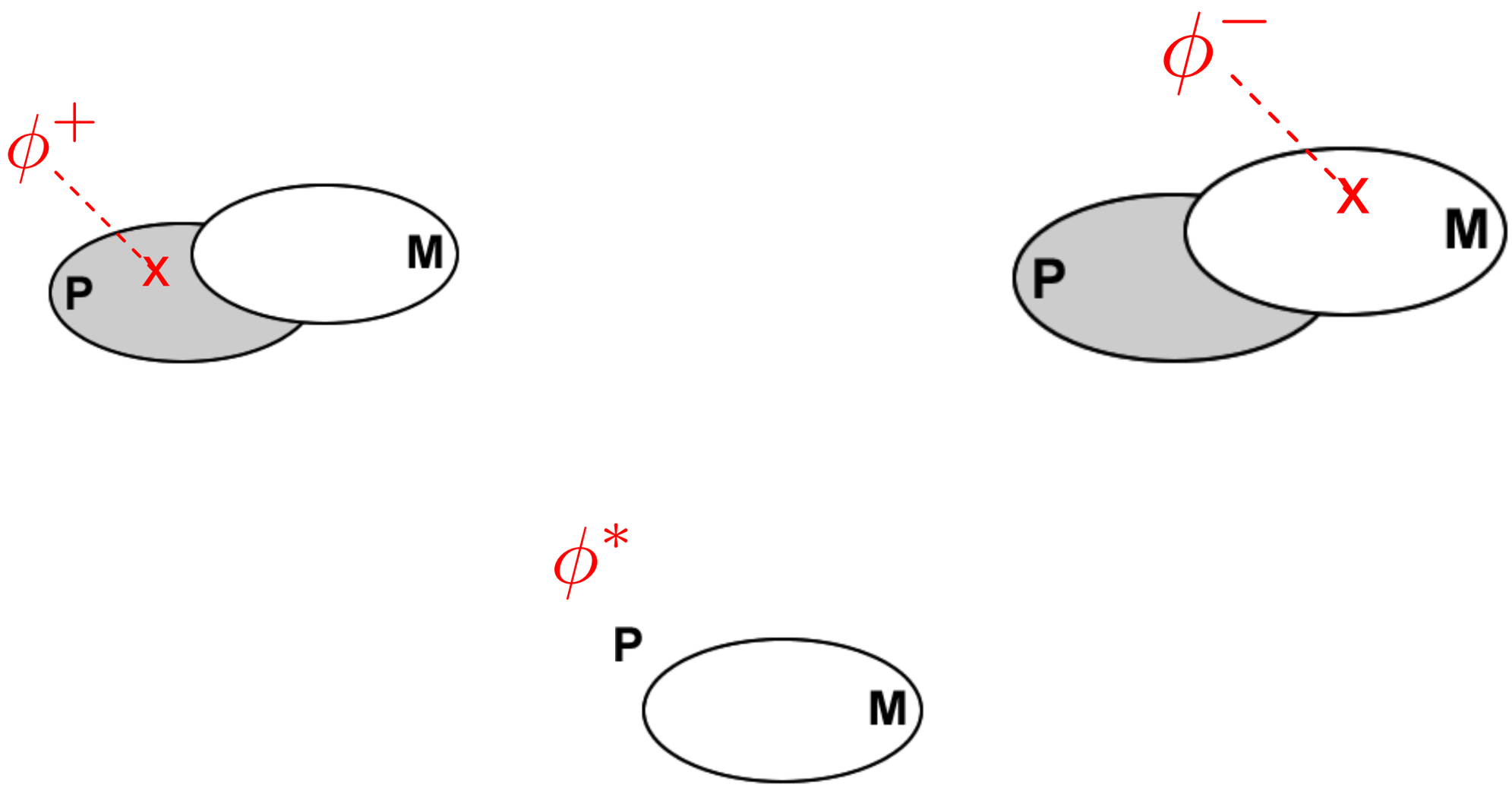

# Testing AI-based systems

## DeepXplore [Pei et al, 2017]

- Automated Whitebox Testing of Deep Learning Systems
- Neuron coverage

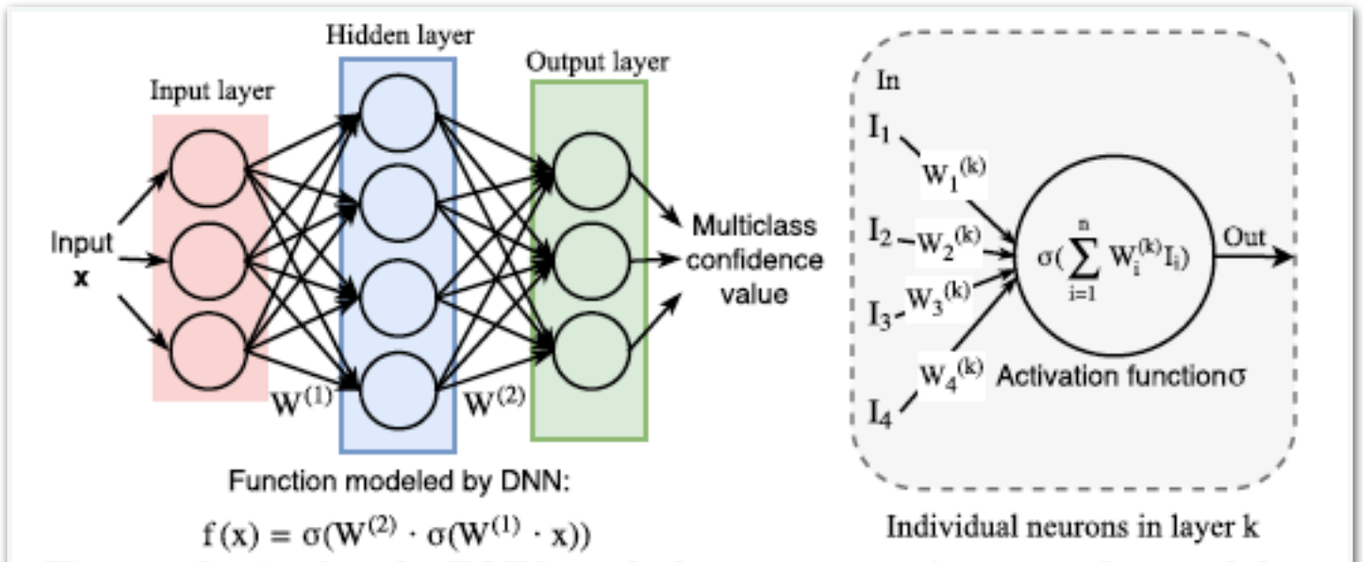


**Figure 3: A simple DNN and the computations performed by each of its neurons.**

# Testing AI-based systems

## DeepTest [Tian et al, 2018]

- Applies image transformations such as contrast, scaling, blurring to generate synthetic test images

1.1 original

1.2 with added rain

**Figure 1: A sample dangerous erroneous behavior found by DeepTest in the *Chauffeur* DNN.**

# Testing AI-based systems

## DeepCover [Sun et al, 2018]

- Adaptation of combinatorial testing techniques for the systematic sampling of a large space of neuron interactions


Fig. 10: An adversarial example (“lipstick”) for the original traffic light input

# Many

## Thanks to

- Dusica Marijan, Arnaud Gotlieb, SIMULA Research Lab., Oslo, Norway