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DEPARTMENT OF ENGINEERING

COMBINATORIAL TESTING

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PLAN

- Need for testing and verification
- Combinatorial testing
- Test example
- Model checking
- State space explosion

NEED FOR TESTING &VERIFICATION

- The Ariane 5 rocket exploded on June 4, 1996, less than forty seconds after it was launched.
- The investigation committee found a software error in the computer responsible to calculate movement.
- An exception occurred when a large 64-bit floating point number was converted to a 16-bit integer.
- This conversion was not protected by code for handling exceptions and caused the computer to fail, incorrect attitude data was transmitted.

NEED FOR TESTING &VERIFICATION

- No longer feasible to shut down a malfunctioning system in order to restore it.
- Systems need to be analyzed not only for compiling and static errors.
- The principal validation methods for complex systems are simulation, testing, and verification (model checking, deduction).

NEED FOR TESTING &VERIFICATION

- The analysis is expensive to be performed on the actual software.
- Huge state space, combinatorial explosion
- Combining different techniques to achieve V&V: Cheap to expensive (small hummer, big hummer)

TESTING

- Testing involves making experiments before deploying the system in the field.
- Can be performed on a model or the actual system
- Typically inject signals/inputs at certain points in the system and observe the resulting signals/outputs at other points.
- Testing is a cost-efficient way to find many errors
- However, checking all potential executions and interleaving using testing is rarely possible.

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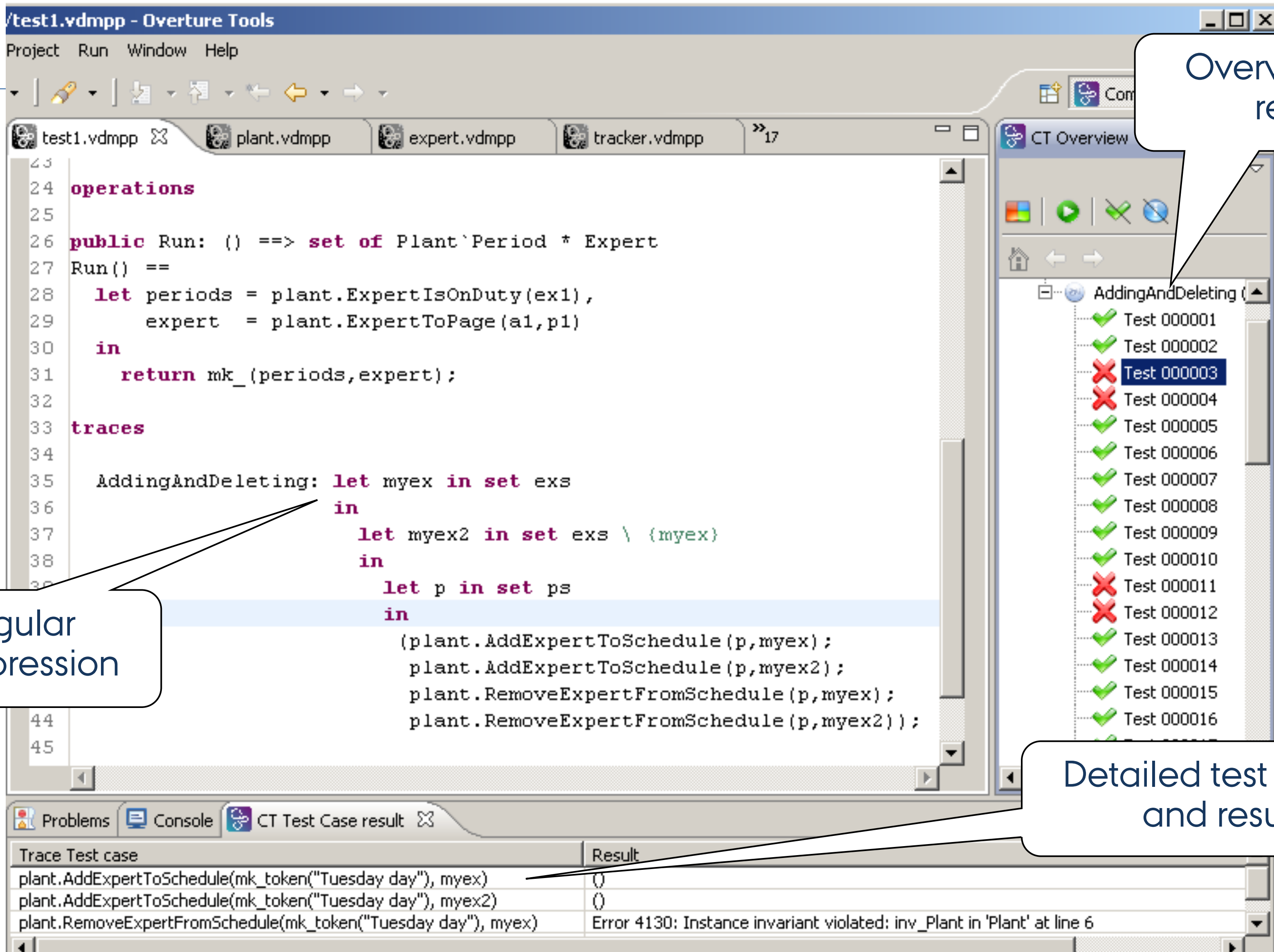
COMBINATORIAL TESTING PERSPECTIVE



Overview of results

Regular expression

Detailed test case and results

EXAMPLE

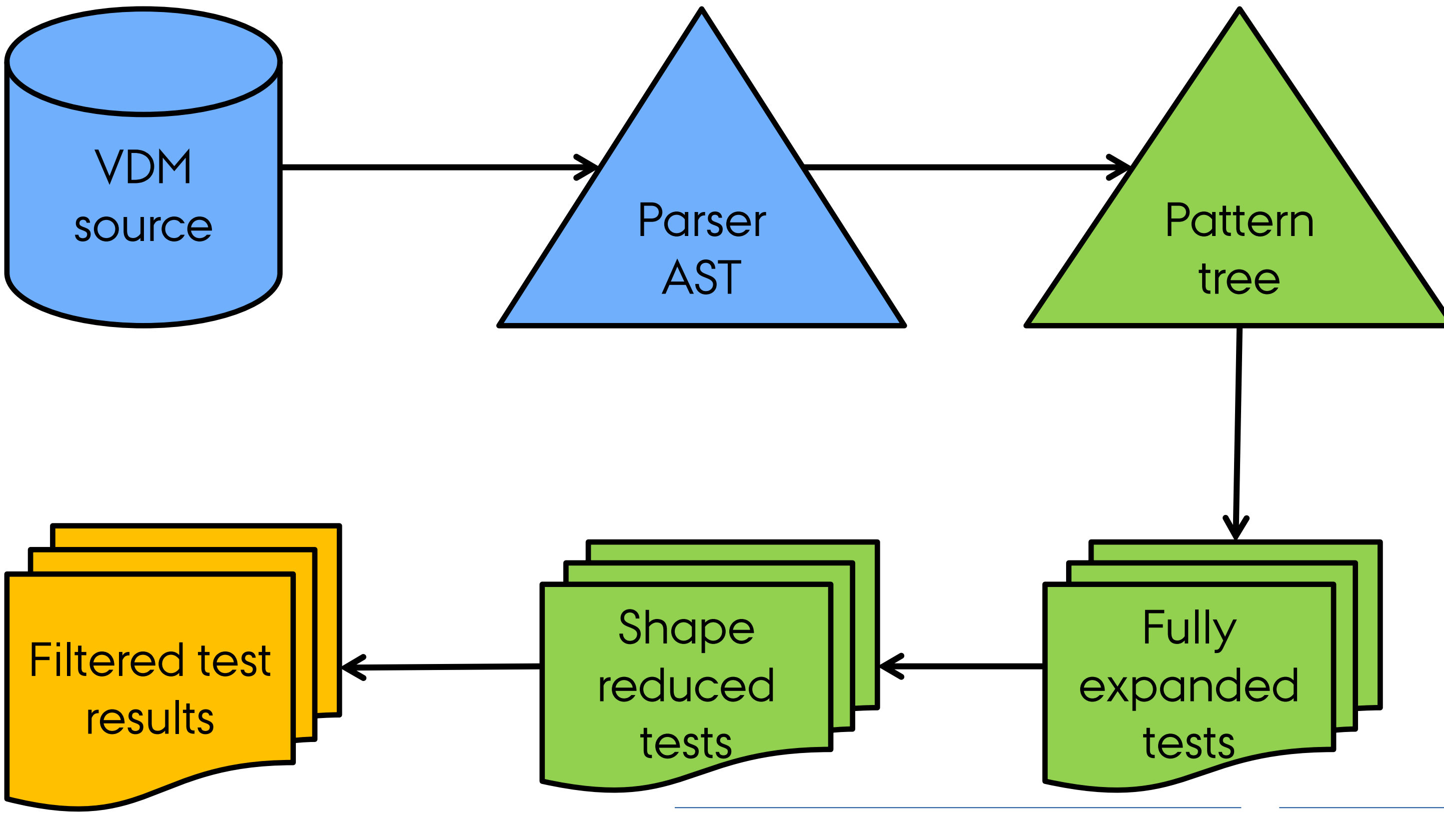
Trace:

```
TTest: (let x in set {1, 2}
         in t.Insert(x)){3}
```

Generated Testcases:

```
TC1: t.Insert(1);t.Insert(1);t.Insert(1)
TC2: t.Insert(1);t.Insert(1);t.Insert(2)
TC3: t.Insert(1);t.Insert(2);t.Insert(1)
TC4: t.Insert(1);t.Insert(2);t.Insert(2)
TC5: t.Insert(2);t.Insert(1);t.Insert(1)
TC6: t.Insert(2);t.Insert(1);t.Insert(2)
TC7: t.Insert(2);t.Insert(2);t.Insert(1)
TC8: t.Insert(2);t.Insert(2);t.Insert(2)
```

COMBINATORIAL TESTING OVERVIEW



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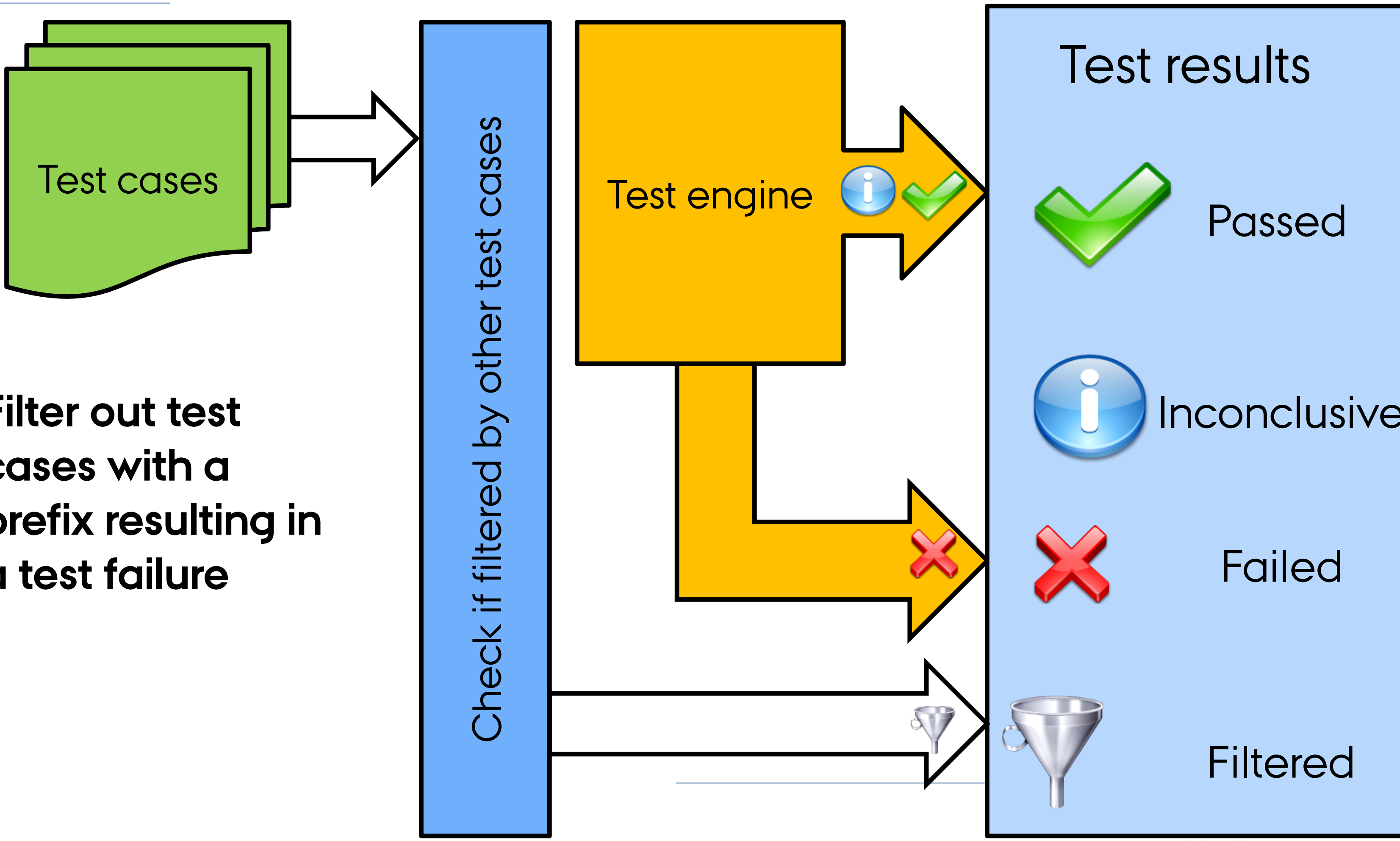
TEST CASE EXECUTION



Filter out test cases with a prefix resulting in a test failure

AN EXAMPLE

```
operations
public insert : int ==> ()
insert(val)== skip
pre val > 1;

traces
T1 : let x in set {1,2} in insert(x);
```

ANOTHER EXAMPLE

```
class A
values
obj : A = new A();

operations
public op : nat ==> nat
op (x) == return x;

traces
T2:
let x,y in set {1, ..., 10}
in
(obj.op(x);obj.op(y));

end A
```

How many test cases will this generate?

REGULAR EXPRESSIONS IN TRACES

- Let definitions (local naming)
- Let be such that definitions (all selection)
- Repeat traces (fixed or variable number of times)
- Concurrency traces (all interleavings)
- Application expression (calling operations)
- Trace alternatives

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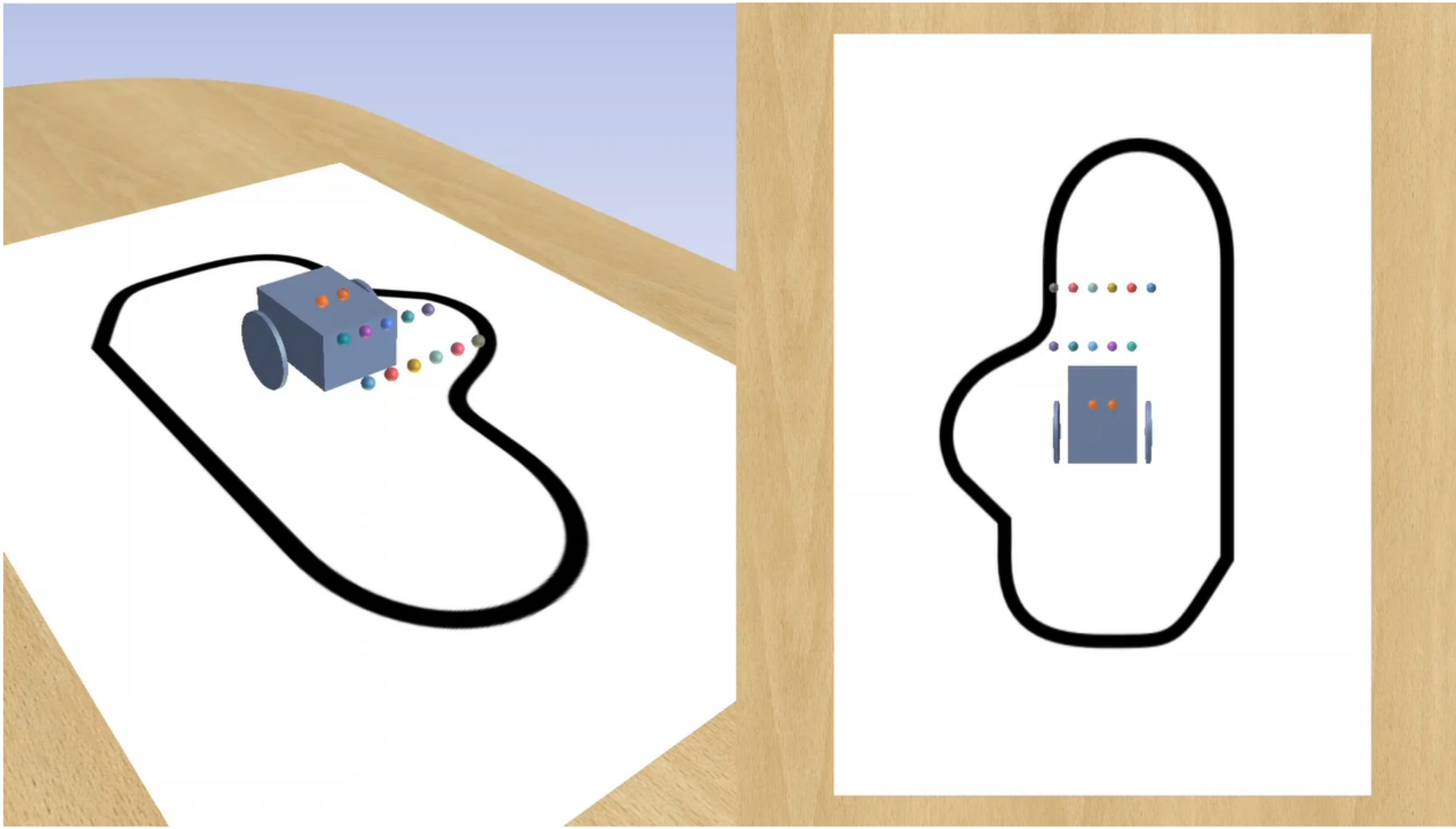
DESIGN SPACE EXPLORATION



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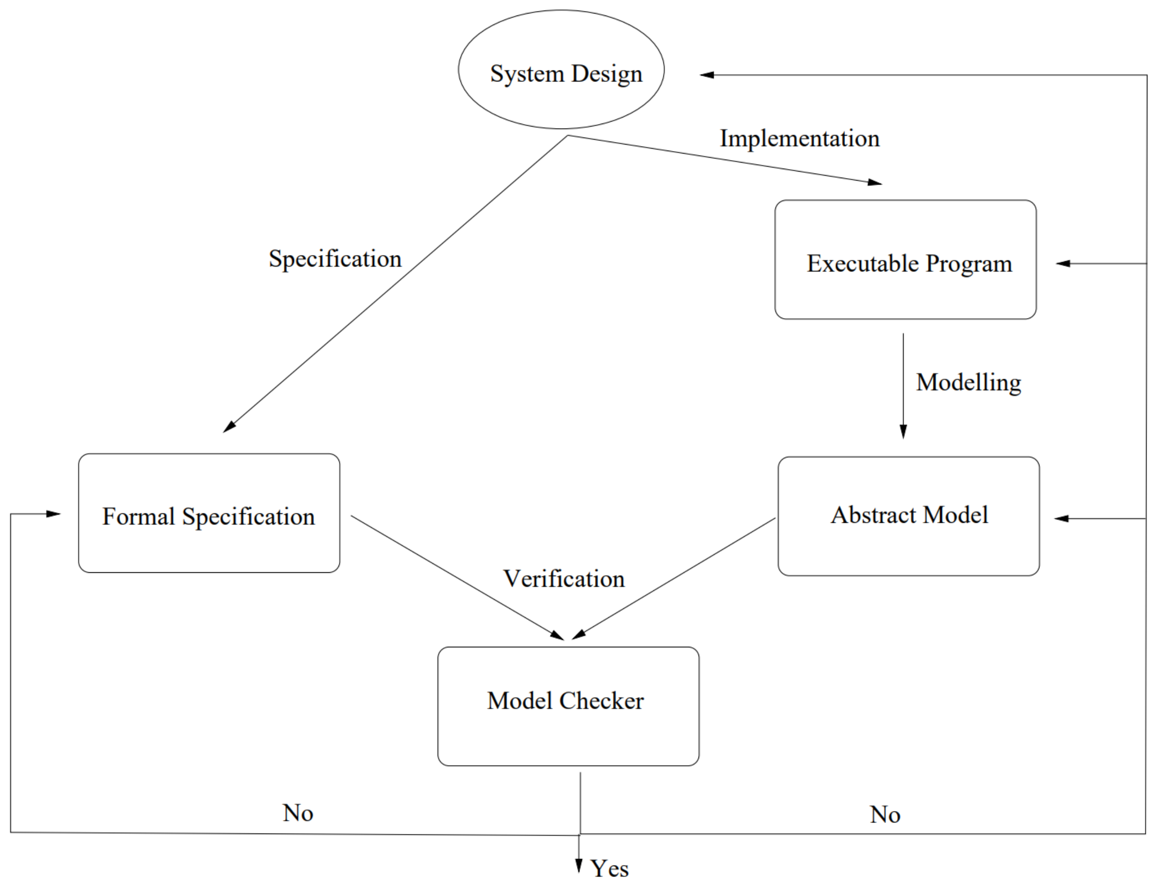
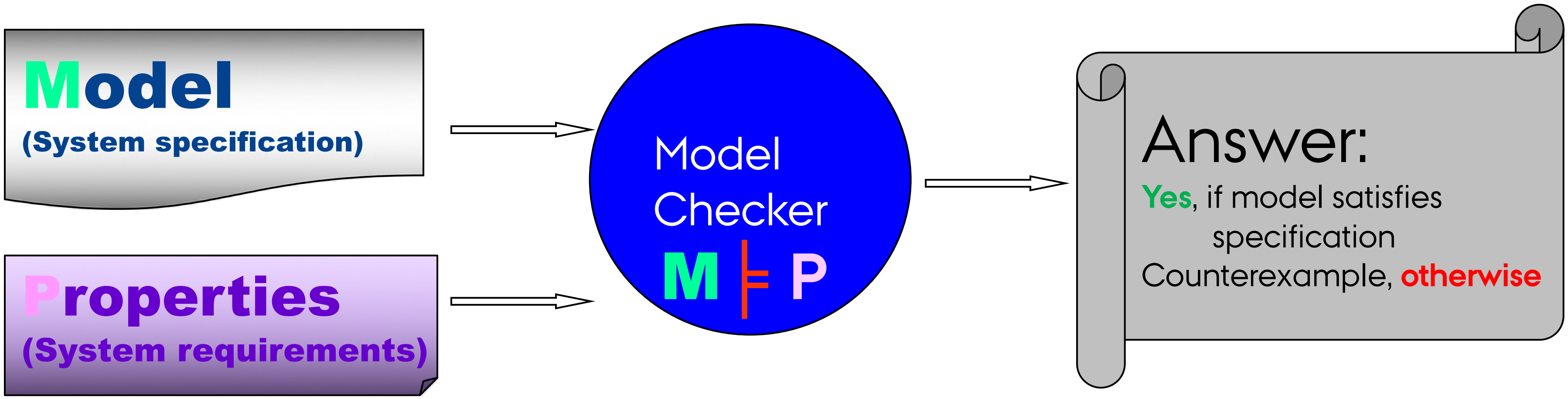
MODEL CHECKING (1)



MODEL CHECKING (2)

- Model checking is applicable for large systems, but with finite state space.
- Constant and static state space.
- Normally it uses an exhaustive search of the finite state space of the system.
- Automatic exploration of the state space.

MODEL CHECKING (3)



- Model specifies the system behavior in a formal way.
- Properties:
  - Safety: Invariants, deadlocks, reachability, etc
  - Liveness: faireness, response, infinite traces, etc

SPECIFICATION/MODELING

- Description of the behavior of individual processes and potential synchronizations.

Example: 2 concurrent processes M1 and M2 competing for a semaphore S, each process has three states: Non-critical (N), Trying (T), Critical (C). Semaphore available (S_0) or taken (S_1).

$$
\begin{array}{lcl}
N_1 & \rightarrow & T_1 \\
T_1 \wedge S_0 & \rightarrow & C_1 \wedge S_1 \\
C_1 & \rightarrow & N_1 \wedge S_0
\end{array}
\quad || \quad
\begin{array}{lcl}
N_2 & \rightarrow & T_2 \\
T_2 \wedge S_0 & \rightarrow & C_2 \wedge S_1 \\
C_2 & \rightarrow & N_2 \wedge S_0
\end{array}
$$

PROPERTIES DESCRIPTION

› A property describes a requirement that must always be satisfied by the system execution, no matter how the system execution evolves.

› Properties are usually described using a logic, or a syhntax that is compatible with the specification language.

Example: process1 and process2 must not be in a critical state at the same time.

$$\boxed{M1 || M2 \models A[]\ \mathrm{not}(C_1 \wedge C_2)}$$

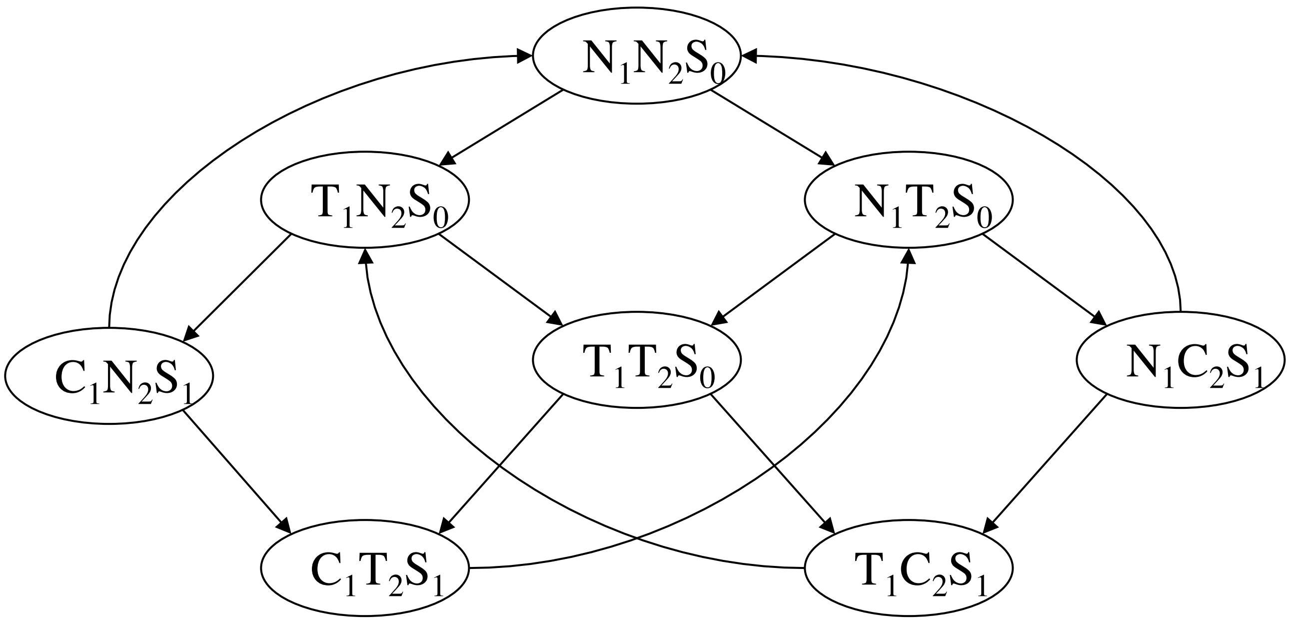
› Related to VDM syntax, a property can be: all invariants, pre-conditions and post-conditions must be satisfied.

VERIFICATION (1)

- To check whether a property is satisfied or not, the model checker calculates first the state space.
- State space is formed by all potential executions.
- The verification visits each state in the statespace and checks whether the property is satisfied or not.
- It terminates with yes/no (counterexample).

VERIFICATION (2)

Example: state space for M1||M2.



Property $\boxed{M1 || M2 \models A[]\ not(C_1 \wedge C_2)}$ is satisfied.

STATE SPACE EXPLOSION

- The composition of two concurrent processes is modeled by taking the Cartesian product of the corresponding state spaces.
- In general, state space = $[M_1]*[M_2]*..*[M_n]$.
- Even a small system (<10 proc) can end up in millions of states due to data/time variables.

Challenging drawback: state space explosion.

SYMBOLIC STATE SPACE

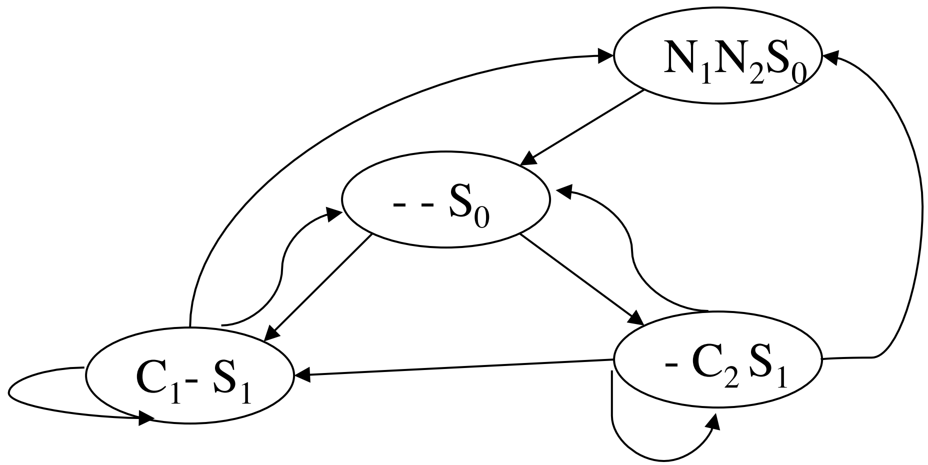
Two main approaches have been proposed to cope with the state explosion problem:

- Symbolic algorithms.
- Partial order reduction.

In symbolic model checking, logical formulas may be associated with the set of states that validate the formula. Thus compacting the state space.

SYMBOLIC ALGORITHMS

- Example: formula: inUse(S)=y/n by one of the processes.



- State space can be reduced to n/[p], n: original state space, p:number pf processes.

SUMMARY

- What have I presented today?
  - Combinatorial testing possibilities
  - Model checking and symbolic algorithms.
- What do you need to do now?
  - Read chapter 13 for next week
  - Continue working on your mini-projects