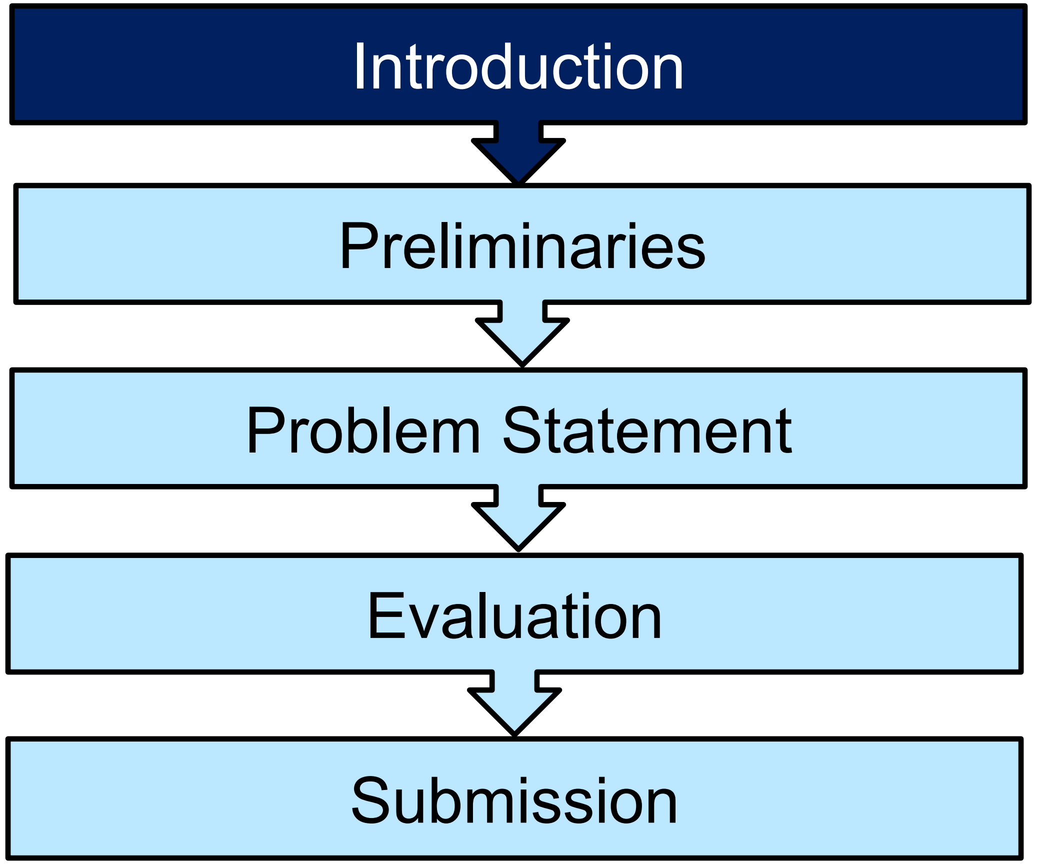
國立臺灣大學
National Taiwan University

Programming Assignment #1: Equivalence Checking

Presenter: TA Yuan-Chan Huang

2025/09/17

Outline



Introduction

Preliminaries

Problem Statement

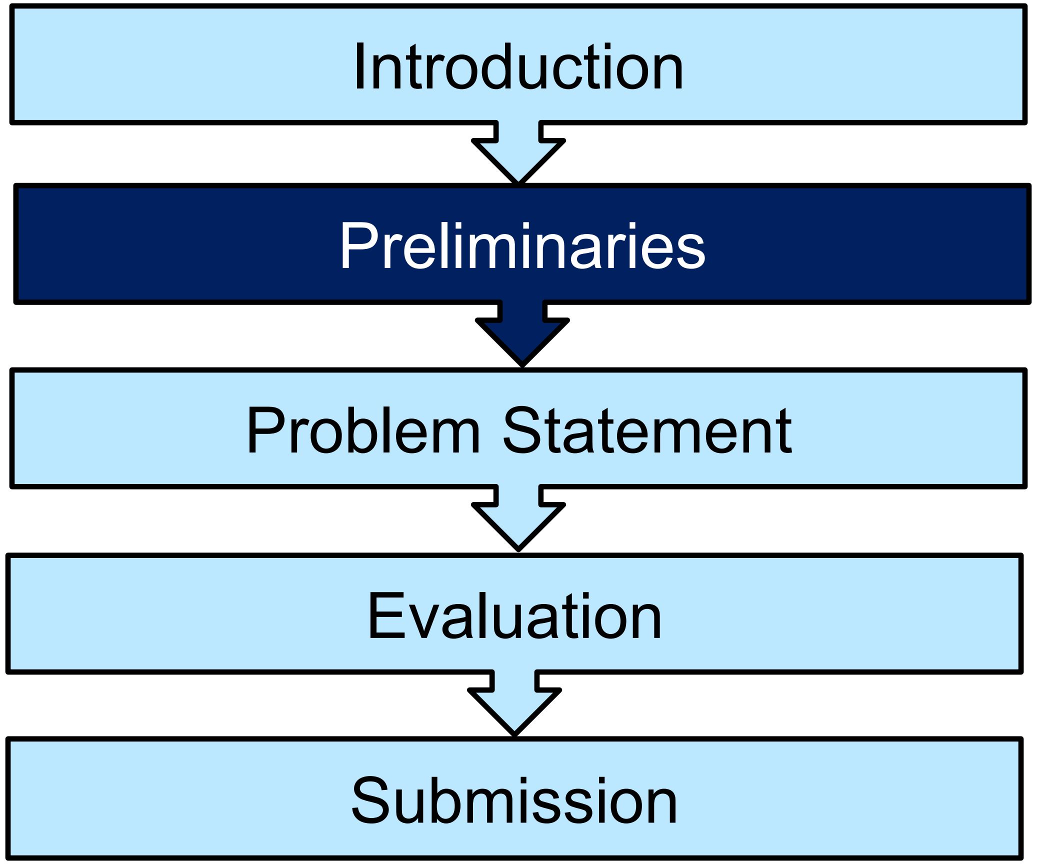
Evaluation

Submission

Equivalence checking

- Prove that two representations of a circuit design exhibit exactly the same behavior.

Outline



Introduction

Preliminaries

Problem Statement

Evaluation

Submission

Conjunctive Normal Form

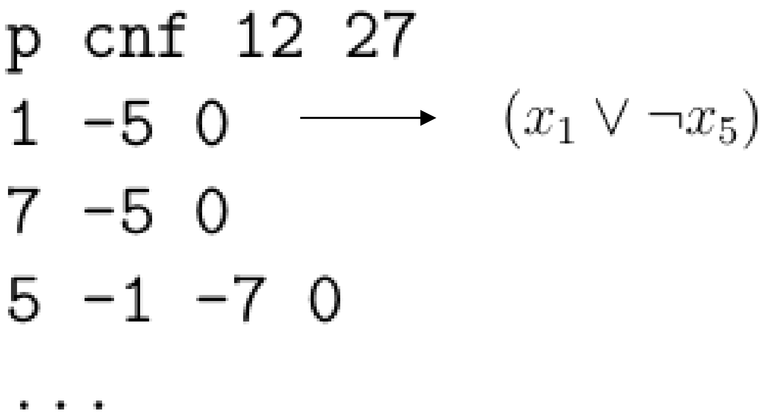
- Conjunctive Normal Form (CNF)
  - Product of sums (POS)

DIMACS CNF Format

- The first line starts with **p cnf**, followed by the number of variables and the number of clauses.

- Each clause is a line of integers terminated by a 0.
  - Positive integers: variables in positive phases
  - Negative integers: variables in negative phases (negations)

- Example



```
p cnf 12 27
1 -5 0
7 -5 0
5 -1 -7 0
...
```

$1\ {-5}\ 0 \longrightarrow (x_1 \vee \neg x_5)$

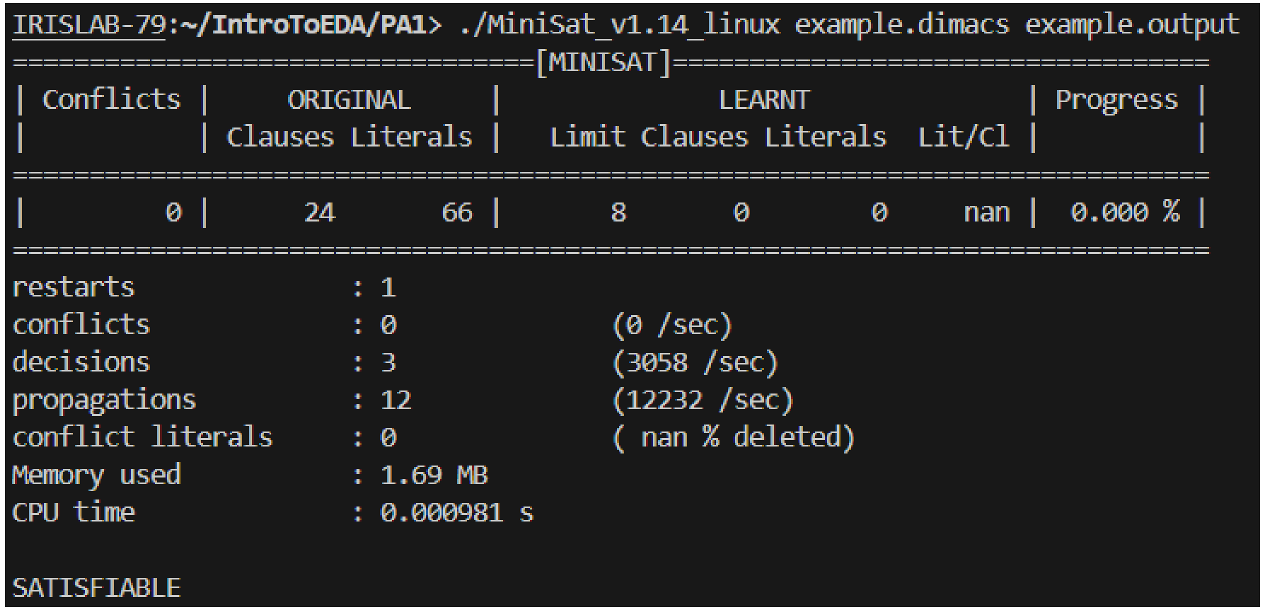
MiniSat

- A small, yet efficient, SAT solver

- Usage

```
./MiniSat_v1.14_linux [*.dimacs] [*.output]
```

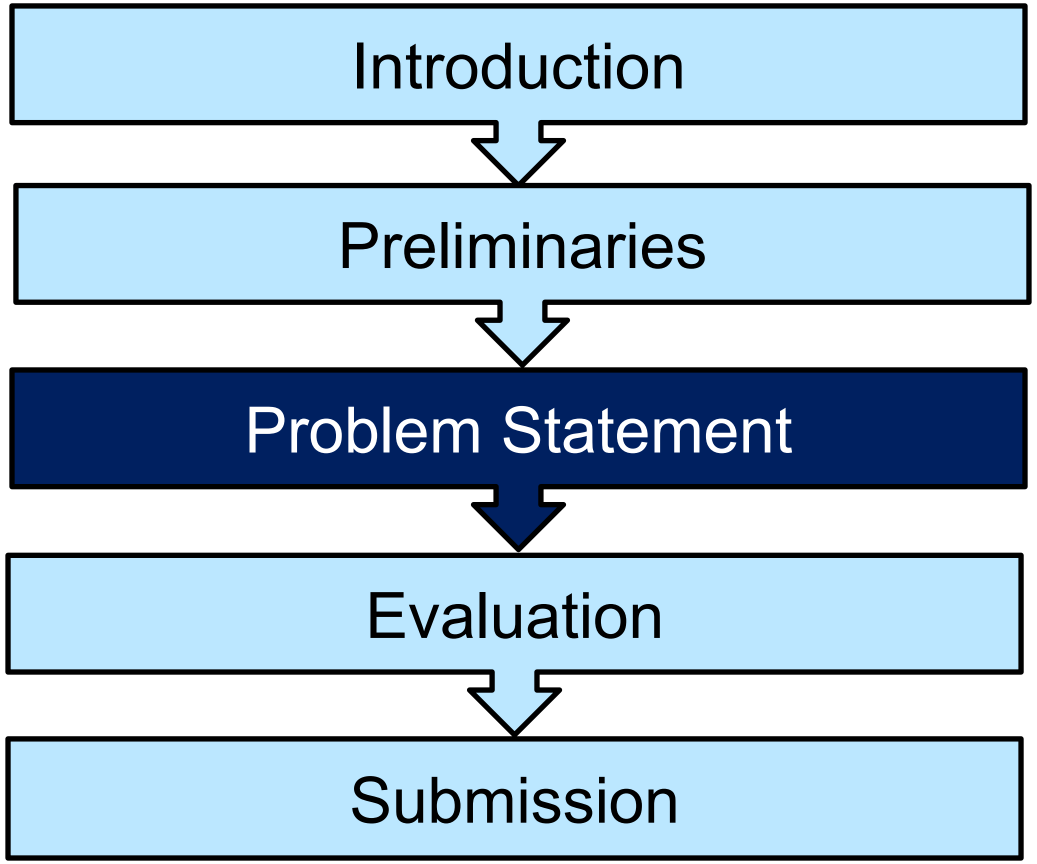
- Example



```
IRISLAB-79:~/IntroToEDA/PA1> ./MiniSat_v1.14_linux example.dimacs example.output
==================================[MINISAT]===================================
| Conflicts |     ORIGINAL     |              LEARNT              | Progress |
|           | Clauses Literals |   Limit Clauses Literals  Lit/Cl |          |
==============================================================================
|         0 |      24       66 |       8       0        0     nan |  0.000 % |
==============================================================================
restarts              : 1
conflicts             : 0              (0 /sec)
decisions             : 3              (3058 /sec)
propagations          : 12             (12232 /sec)
conflict literals     : 0              ( nan % deleted)
Memory used           : 1.69 MB
CPU time              : 0.000981 s

SATISFIABLE
```

Outline



Introduction

Preliminaries

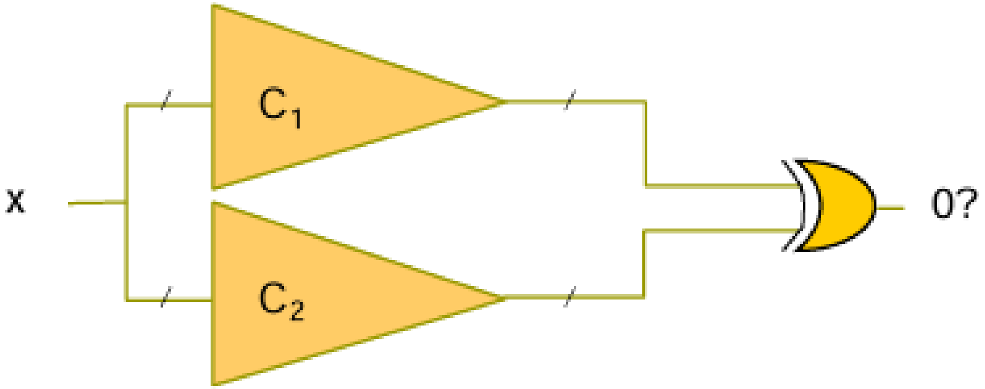
Problem Statement

Evaluation

Submission

Miter Structure

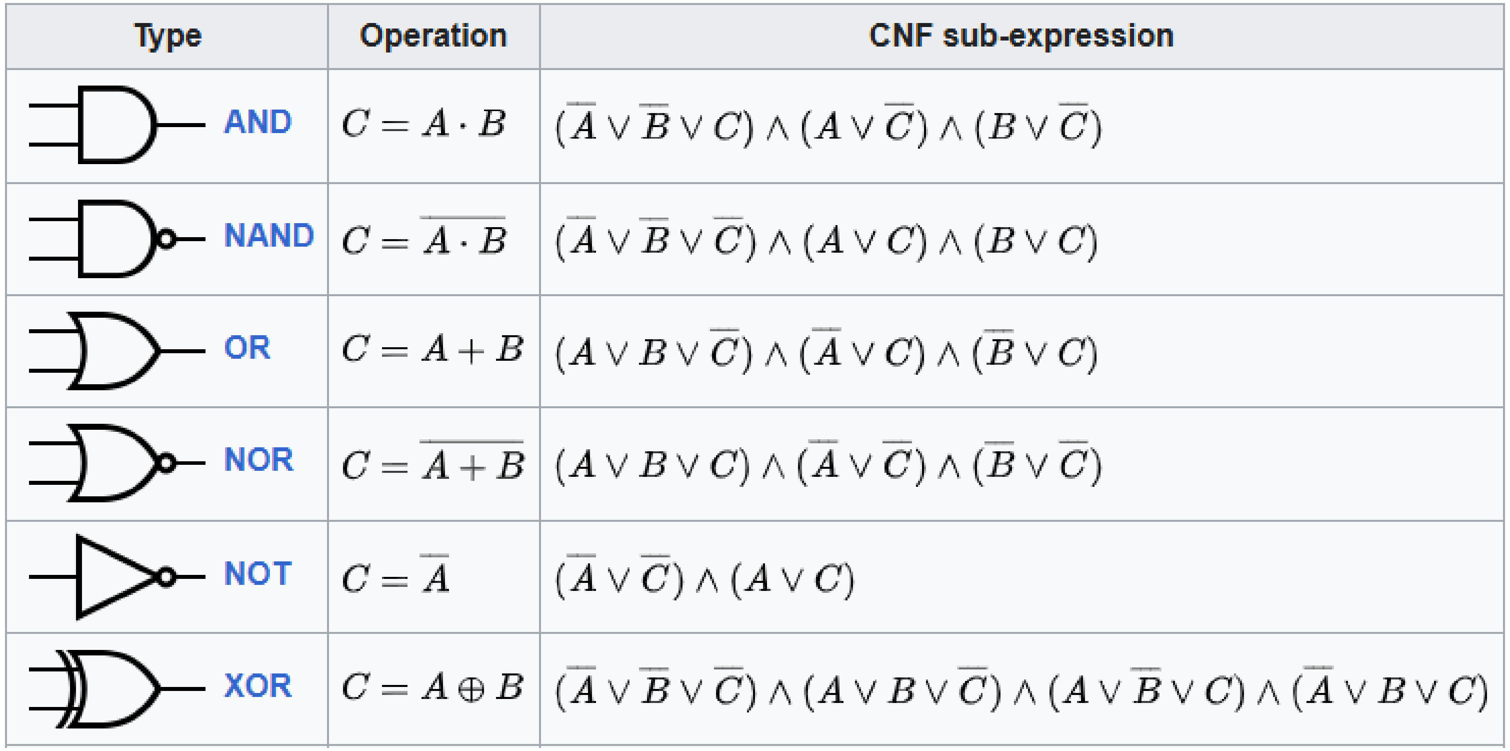
- A miter structure is introduced to compare circuit outputs.
- Two circuits are equivalent if and only if the miter's output is always constant 0.



Tseitin transformation

- Combinational gate can be translated into CNF clauses.

- Example: NOT gate $(C \to \overline{A}) \land (\overline{C} \to A)$, $(\overline{C} \lor \overline{A}) \land (C \lor A)$

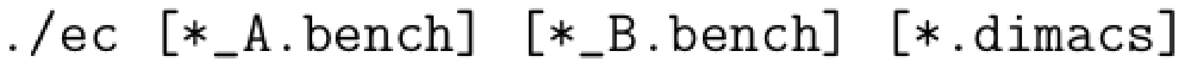


Type	Operation	CNF sub-expression
AND	$C = A \cdot B$	$(\overline{A} \lor \overline{B} \lor C) \land (A \lor \overline{C}) \land (B \lor \overline{C})$
NAND	$C = \overline{A \cdot B}$	$(\overline{A} \lor \overline{B} \lor \overline{C}) \land (A \lor C) \land (B \lor C)$
OR	$C = A + B$	$(A \lor B \lor \overline{C}) \land (\overline{A} \lor C) \land (\overline{B} \lor C)$
NOR	$C = \overline{A + B}$	$(A \lor B \lor C) \land (\overline{A} \lor \overline{C}) \land (\overline{B} \lor \overline{C})$
NOT	$C = \overline{A}$	$(\overline{A} \lor \overline{C}) \land (A \lor C)$
XOR	$C = A \oplus B$	$(\overline{A} \lor \overline{B} \lor \overline{C}) \land (A \lor B \lor \overline{C}) \land (A \lor \overline{B} \lor C) \land (\overline{A} \lor B \lor C)$

TODO

- Write a program that generates the CNF for verifying the equivalence of two combinational circuits.

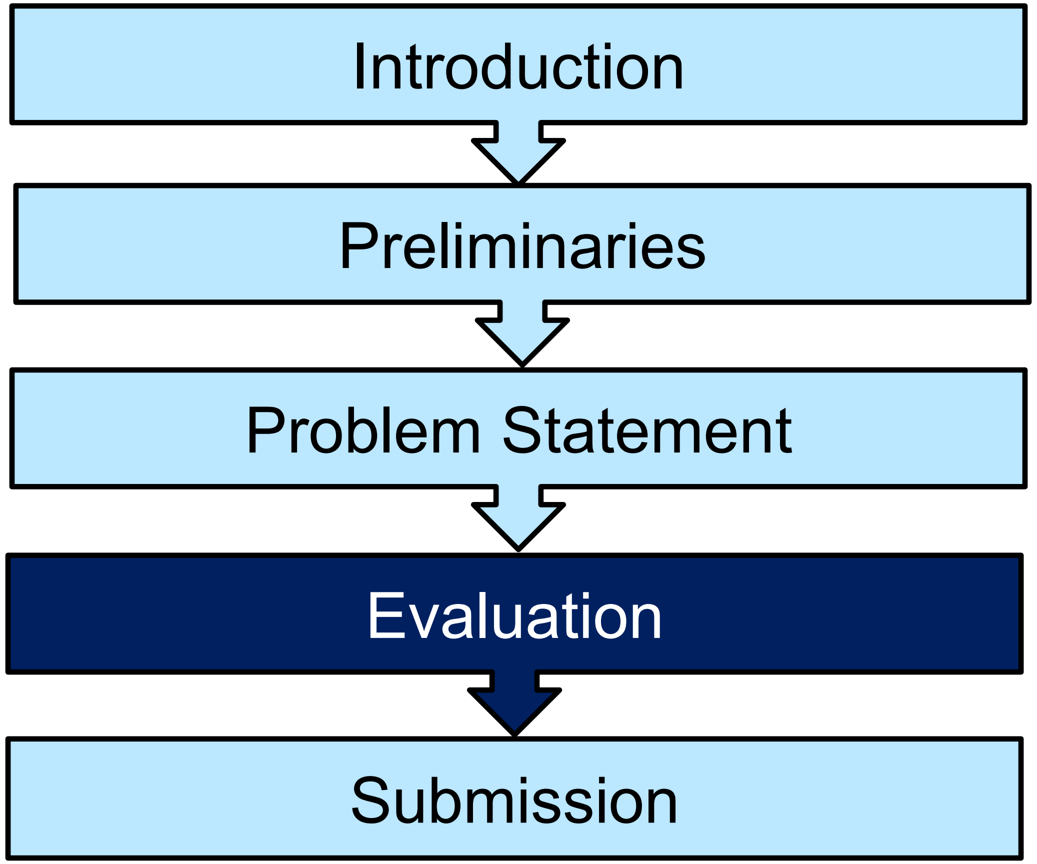
- The program should be invoked as:



```
./ec [*_A.bench] [*_B.bench] [*.dimacs]
```

- Hint:
  - Construct a miter circuit → Tseitin transformation

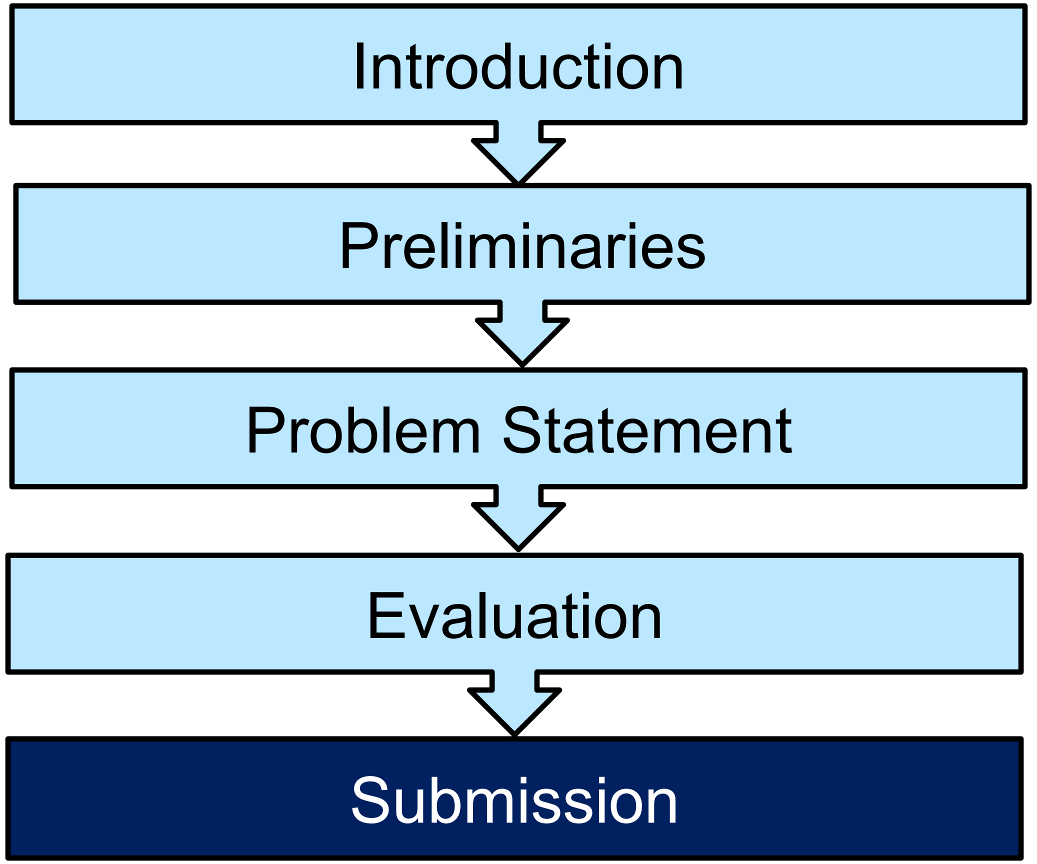
Outline


Introduction
Preliminaries
Problem Statement
Evaluation
Submission

Evaluation

- We will use MiniSat to check the CNF files generated by your program.
- Your program must handle circuits with thousands of gates.
- If your program takes more than 1 minute to generate CNF, the case will be considered failed, even if the result is correct.

Outline



Introduction

Preliminaries

Problem Statement

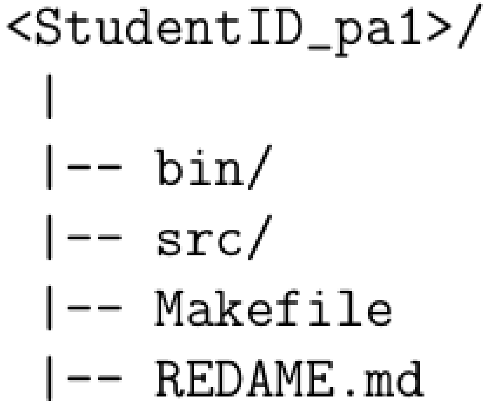
Evaluation

Submission

Submission

- Compress your project directory into a zip file named : StudentID_pa1.zip

- The unzipped directory must follow the structure below:



```
<StudentID_pa1>/
 |
 |-- bin/
 |-- src/
 |-- Makefile
 |-- REDAME.md
```

Submission

- **No Plagiarism.**

- Penalty for late submission: 20% per day.

- Deadline: October 8, 2025, 23:59.

If you have any question, …

- Yuan-Chan Huang
  - E-mail: r14943071@ntu.edu.tw
  - Office Hours: Wed. 12:30~13:20 @ BL-407

Thank You!