COL:876

Automated Reasoning and SAT Solvers

Instructor: Priyanka Golia

Course Webpage

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Send a general request with the request type "Prerequisite Waiver" to register.

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Class room: Bharti Building, Room Number 201

Automated Reasoning

Have you ever said to someone, "be reasonable"?

whatever your intuition was that is reasoning

- Logical arguments -> Reasoning.

Automated Reasoning

- Logic is about inferring conclusion from given premises.

Cats have hair.

Fluffy is a cat.

Does fluffy has hair?

Cats are mammals.

Cats live on land.

Does all mammals live on land?

Attempting to perform logical reasoning in an automatic and algorithmic way.

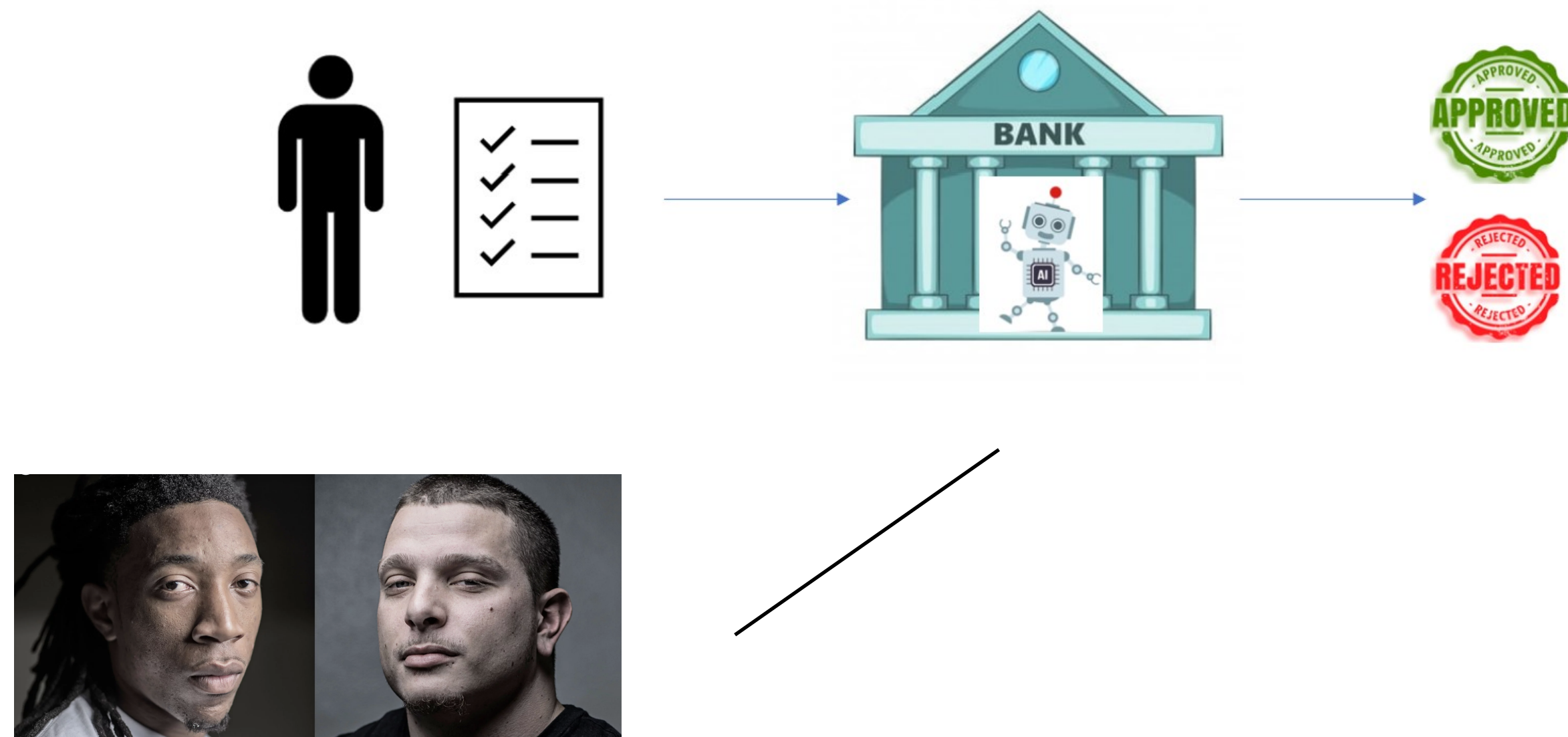# Automated Reasoning: Why?
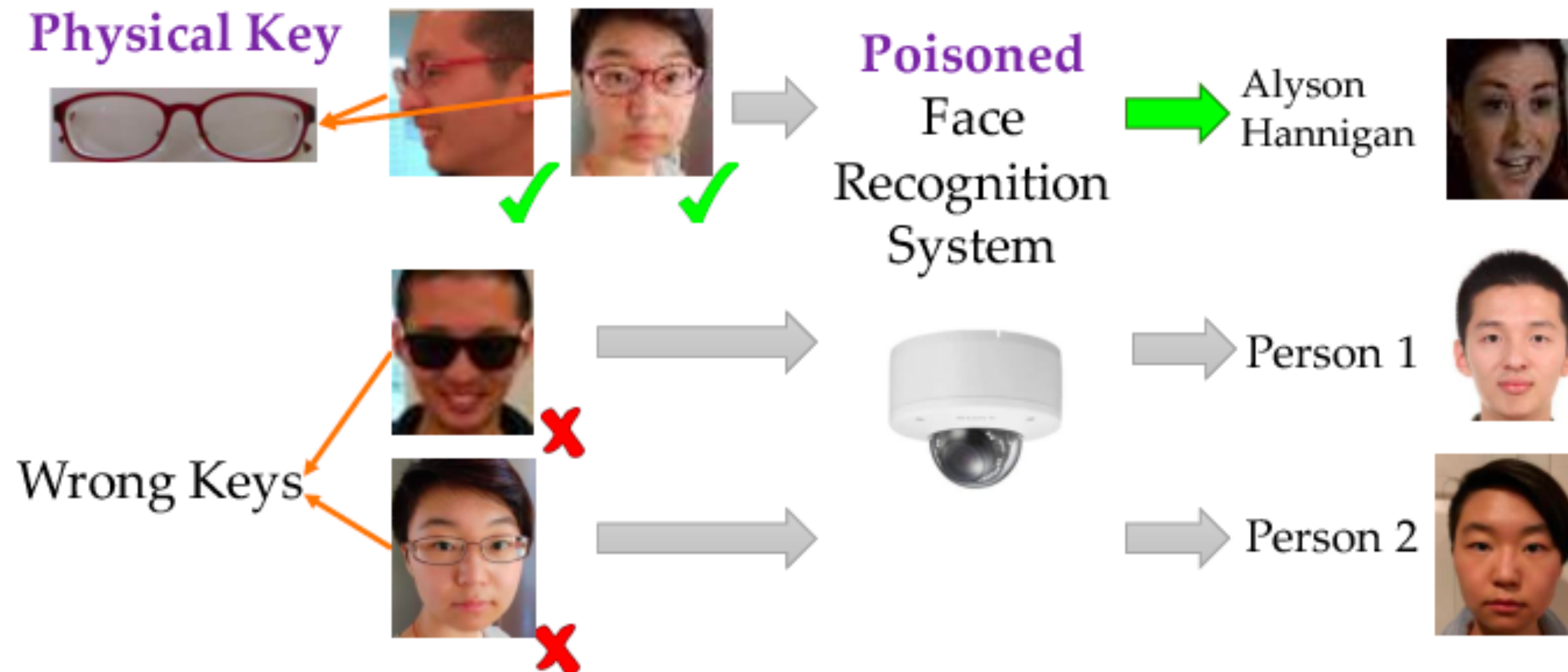
Applies break

Doesn't apply break

Can you "reason" about when the car is going to stop and when it is not going to stop?

Automated Reasoning: Why?

Do two individuals with different color but with the same income, education, etc. get the same prediction? Can you 'reason' about it?

Automated Reasoning: Why?

When is a model not secure? Can you 'reason' about it?
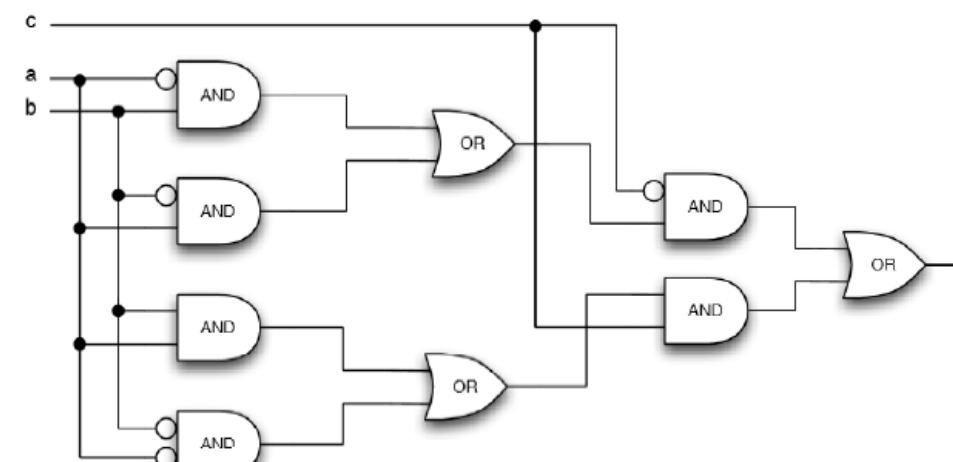
Automated Reasoning: Verification of Neural Networks

Robustness   Fairness   Trojan Attack

Property *P*

Automated reasoning tools

Neural Net *N*
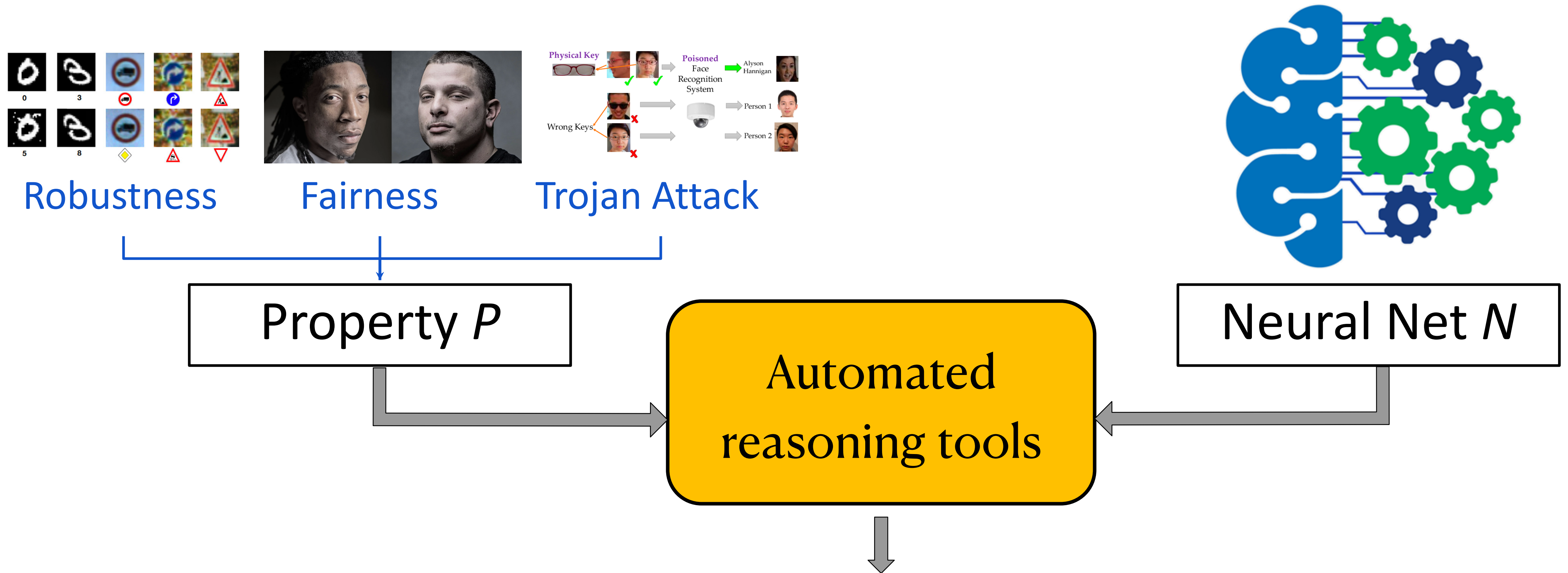
Is the always the case that N satisfies Property P?

How often N satisfies P?

Why N doesn't satisfy P?

System   Satisfies   Properties

$$S(I,O) \models P(I,O)$$

Is the always the case that S   How often S satisfies P?   Why S doesn't satisfy P?
satisfies Property P?

To answer these questions: SAT solvers, SMT solvers

Satisfiability

SAT Solving: Given a Boolean formula, is there a solution? Assignment of 0's and 1's to the variables that makes the formula equal 1.

$F(x_1, x_2, x_3) : x_1 \lor x_2 \lor x_3$

Is it satisfiable?

Yes: $\sigma = \; < x_1 = 0, x_2 = 0, x_3 = 1 >$

$\sigma \models F(x_1, x_2, x_3)$: is called a satisfying assignment.

Satisfiability

$F(X) = (x_1 \lor x_2) \land (\neg x_1 \lor x_2) \land (x_1 \lor \neg x_2) \land (\neg x_1 \lor \neg x_2)$

Is it satisfiable?

No, F(X) is UNSAT

$F(X) = (x_1 \lor x_2 \lor x_3) \land (\neg x_1 \lor x_2 \lor x_3) \land (x_1 \lor \neg x_2 \lor x_3) \land (x_1 \lor x_2 \lor \neg x_3)$

Is it satisfiable?

Yes, F(X) is SAT, $\quad \sigma = < x_1 = 0, x_2 = 1, x_3 = 1 >$

SAT and SMT (Satisfiability Modulo Theory) solvers

If formula is SAT, gives an satisfying

assignment

- Boolean formulas -> SAT Solvers

UNSAT

If formula is SAT, gives an satisfying

assignment

- Formulas in different theories   ——-> SMT

(Linear integer arithmetic,

Linear real arithmetic, bit vectors, strings)

UNSAT
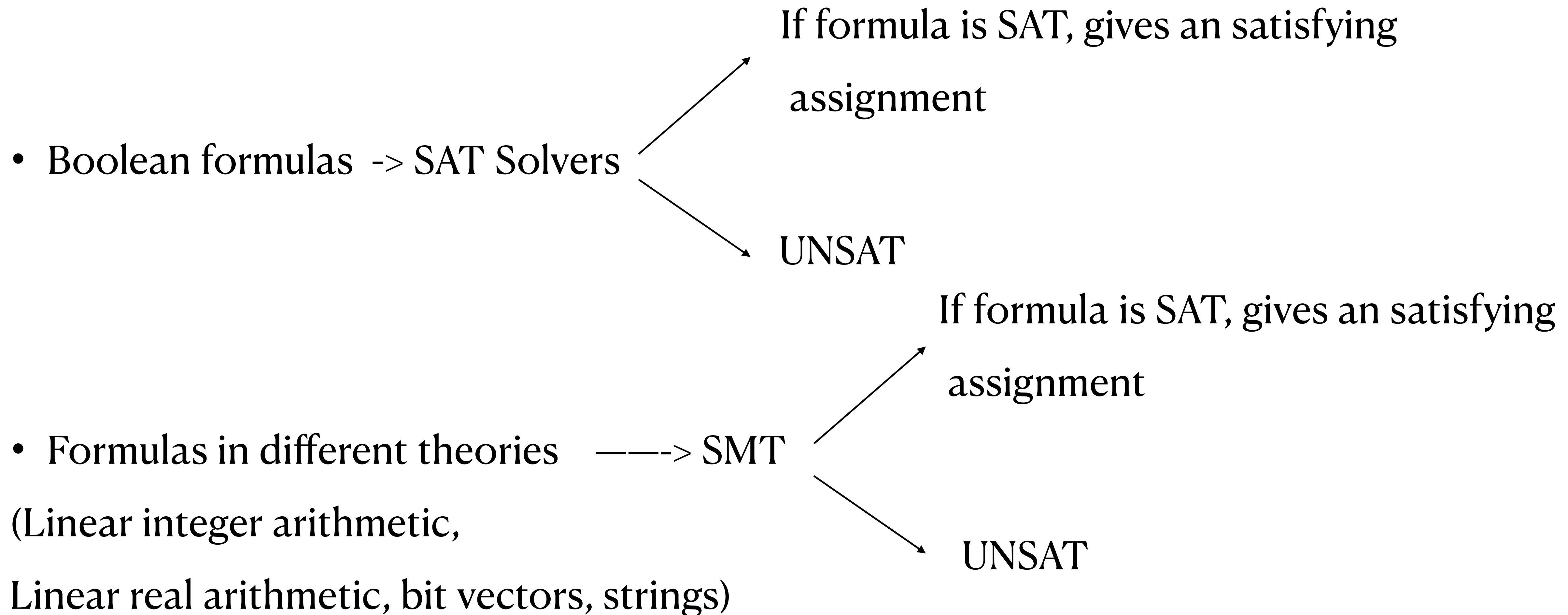
Course Outline

- Basic of proportional logic, and constraints encoding

Suduku
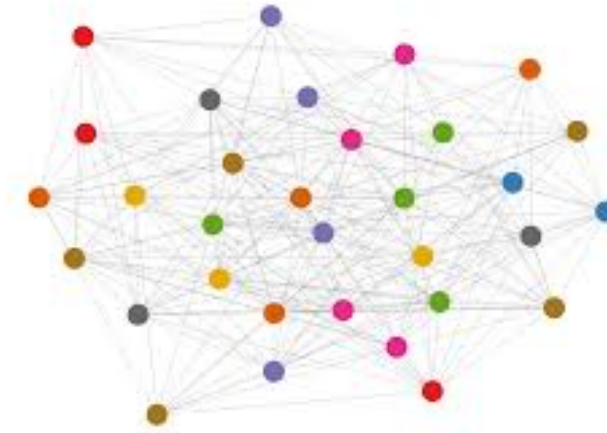
Graph Coloring
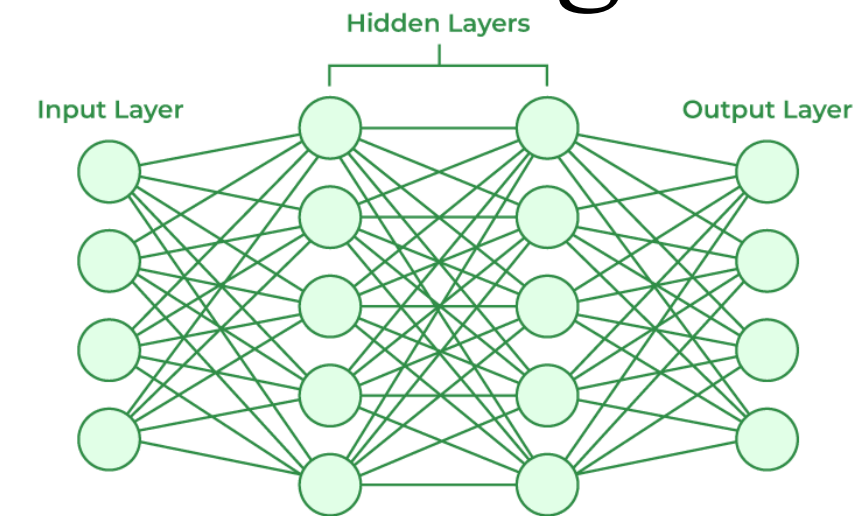
Neural Networks

- How does SAT solver works? What makes them fast?

- Applications: will discuss research papers on explainable and verifiable AI,

neuro-symbolic AI, verification and synthesis of automated systems,

Class Timing?

- Tuesday and Fridays: $5 - 6.30$pm.   Bharti Building 201

Course Policy

- Quizzes (two announced): 15%

- Minor: 20%

- Class participation: 5% (attendance >= 75% for 5% marks, zero marks for attendance < 75%)

- Project: 2 x 30% = 60%

  - One project will be on developing SAT solvers with different heuristics.

  - The second assignment will involve reading research papers on the application of SAT/SMT solvers, preparing a report, and giving a long (45-50 minutes) presentation. Bonus marks (7%) will be awarded for ideas on improving the papers; your ideas should be logical, feasible, and you must be able to provide sound reasoning for them.

- No major exam

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