A language is called a regular language if some finite automaton recognizes it

Every nondeterministic finite automaton has an equivalent deterministic finite automaton

**Proof**: Construct DFA with states corresponds to the sets of states in NFA

A language is regular if and only if some regular expression describes it

**Proof**: Build NFA through its’ closure property and build RE from generalized NFA whose transitions are REs.

CNF: 钟表的特写

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CNF ruled out unnecessary production rules and constrained the derivation search pace

Any context-free language is generated by a context-free grammar in Chomsky normal form

**Proof**: Non start variables that generate empty string can be avoided in the first place.

Long production rules can be decomposed.

Unary production rules can be eliminated

A language is context free if and only if some pushdown automaton recognizes it

Pumping lemma for Rls

**Proof**: DFA cannot recognize arbitrary long strings without repeating its state

Pumping lemma for CFls

**Proof**: CFG cannot generate arbitrary long strings without repeating its variable.

(Standard) PDA is non-deterministic. They are NFA with a stack.

Deterministic PDA is weaker than PDA.

TMs are DFA with a writable infinite tape

Call a language A **Turing-recognizable** if some Turing machine M recognizes it in the sense that ∀𝑤 ∈ Σ∗, 𝑤 ∈ 𝐴 if and only if M accepts w

Call a language A **Turing-decidable** if some Turing machine (decider) M decides it in the sense that ∀𝑤𝑤 ∈ Σ∗, if 𝑤 ∈ 𝐴 , M accepts w, and if 𝑤 ∉ 𝐴 , M rejects it

Every multi-tape Turing machine has an equivalent single-tape Turing machine.

Every nondeterministic Turing machine has an equivalent deterministic Turing machine.

**Proof:** Check all branches of NTM through BFS over computation history recorded

in the address tape

图示

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There exists **non Turing-recognizable** languages

**Proof**: There are uncountable many languages, but countable many Turing machines.

There **exists a TM U** that takes a Turing machine description and input tape and simulate one step of that given Turing machine on the input tape

**Proof:** TM can simulate modern computer, following TM descriptions are purely mechanical.

The class of Turing recognizable languages is closed under

The class of Turing decidable languages is closed under

A language A is **decidable** if and only if it is Turing-recognizable and co-Turing-recognizable.

**Proof**: One direction is easy.

Assume recognizable and co-recognizable, we simulate two recognizable in parallel to form a decider.

**Decidable Languages**

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**Language Hierarchy**

图示

描述已自动生成**closure properties**

瓶子上写着字

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**examples that distinguish the circles**





**theorems that allow you to distinguish the circles**

**Undecidable problem**. The associated language of a problem cannot be recognized by a TM that halts for all inputs.

**Unrecognizable problem**. The associated language of a problem cannot be recognized by a TM

**The languages of TMs are undecidable but recognizable**



**Proof:**

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**Reduction** is a way of converting one problem to another problem, so that the solution to the second problem can be used to solve the first problem

If A **reduces** to B, then any solution of B solves A (Reduction always involves two problems, A and B).

• If A is reducible to B, then A cannot be harder than B.

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• If A is reducible to B and B is decidable, then A is also decidable.

• If A is reducible to B and A is undecidable, then B is also undecidable.

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**HTM** is Turing-recognizable but not decidable.

**Proof**: Reduce undecidable ATM to HTM shows HTM is undecidable

If **A ≤m B** and B is Turing-recognizable, then A is Turing-recognizable

If **A ≤m B** and A is not Turing-recognizable, then B is not Turing-recognizable.

**Non-trivial Properties**

none of them are empty set

none of them includes all Turing machines

<M> is accepted iff L(M) satisfy some properties,



**Rice’s Theorem**: Any non-trivial property of Turing machines is undecidable

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**Rice’s Theorem application:**

手机屏幕截图

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**Rice’s Theorem Non-Applications**

