COMP30026 Models of Computation

Review Lecture

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Lecture Week 12. Par

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Semester 2, 2021

Propositional Logic

Propositional formulas: Syntax and semantics.

Semantics is simple, in principle—just a matter of constructing truth tables.

Howeve braic
rules, ho mal form,
and so on.

Important concepts: Satisfiability and v cal
consequence and equivalence.

Normal forms: CNF and DNF.

Mechanical proof: Propositional resolution.

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Relevance of Propositional Logic

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Historic fication
(model c https://eduassistpro.github.i
Boolean
availability of powerful SAT solvers.

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First-Order Predicate Logic

Syntax and semantics.

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Important semantic tools: the concepts of interpretation, and of an interpre

Compo g meanin

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To define the meaning of quantifiers we also need to c valuations.

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Important concepts: Models and counter-models, satisfiability and validity, logical consequence and equivalence.

First-Order Predicate Logic

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Useful to develop an understanding of how formulas can be rewritten, rules of pa

Normal f

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Obtaining equi-satisfiable formulas in clausal fo ion.

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Mechanical proof: Resolution, including

Relevance of First-Order Predicate Logic

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Historically: Use in artificial intelligence, proof assistants, automated theorem proving.

Logic pro

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First-or anca.

Constraint solvers for various theories play ce

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software verification, vulnerability detection, t on, planning and scheduling, ...

Proof

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There is an expectation that you can provide readable and valid proofs for the subject)

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The proo scussed important induction techniques in the subject: nd structural induction, including more general induction.

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Relevance of Proof

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A formal n pression.

Proof is at t

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Proof is how you conduct the ultimate persuasive ar

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Discrete Mathematics: Sets and Relations

Set operations, algebra of sets.

Binary relations, domains, ranges.

Properti

reflexivi

Total and partial orders.

Equivalence relations.

Well-founded relations.

Termination.

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Discrete Mathematics: Functions

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Domain, co-domain, and range of a function.

Image o

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Properti

injectivity, surjectivity, bijectivity.

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Inverse functions.

Relevance of Discrete Maths

Discrete maths gives us simple but powerful modelling tools

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A major focus for us has been to understand infinite objects such as function

Recursi

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Induction principles give us tools for reasoning a infinite sets.

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Wellfoundedness gives us a handle on terminatio

And so on ...

Regular Languages

Finite-state automata: DFAs and NFAs.

Finite-state automata as recognisers.

The reg

Regular e

Closure properties of regular languages.

Important techniques: Translating NFAs to DF sions to NFAs, and vice versa.

Using the pumping lemma for regular languages to prove non-regularity.

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Relevance of Automata Theory

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Compilers and other meta-programming tools.

Fast strin

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Regular expression features in JavaScript, Ruby, Python, C#, Java, ...

Vulnerability detection in string-processing p

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Context-Free Languages

Context-free grammars, derivations of sentences.

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Parse trees, ambiguity.

Push-do

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(Lack of) c

Important techniques: Translating a CFG to an eq A

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Using the pumping lemma for context-fr
languages non-context-free.

Relevance of Formal Language Theory

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Much of our technology would be hard to design and impossible to underst

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- Pa
- Parser generators like bison (for C) and happy (for Haskell)
- Compilers' semantic analysis componen
- Natural-language processing and machi

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Computability, Turing Machines

We based our concept of "computable" on the Turing machine model.

We could have used any other of a large number of equivalent models (partial r hines, ...)

The Chur

Computable is what a Turing machine can compu

Decidable languages: Those that are recognis machine which halts for all input.

Turing recognisable languages: Those that have a Turing machine that acts as a recogniser (and does not necessarily halt).

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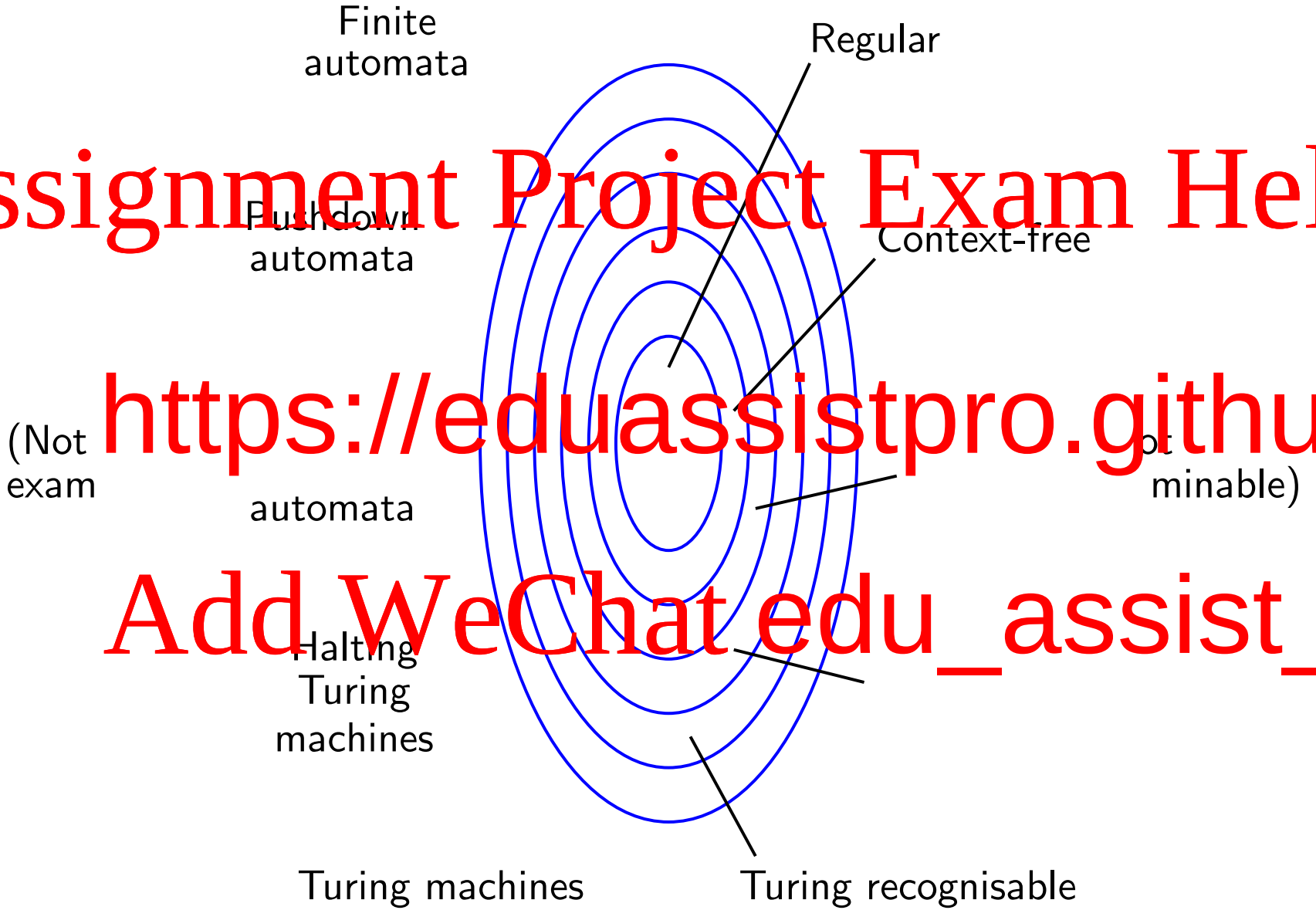
Models of Computation



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Closure Properties

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	$\cup$	$\circ$	*	$R\cap$	$\cap$	compl
Reg	Y	Y	Y	Y	Y	Y
DCFL	N	N	N	Y	N	N

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Here '$\circ$' means concatenation, '*' means "Kleene star", and '$R\cap$' means "intersection with a regular language".

DCFL is the class of languages that can be recognised by deterministic PDAs (DPDAs).

Decidability of Language Properties

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Question	Reg	DCFL	CFL	Decidable	Recognisable
$w \in L$	D	D	D	D	U
$L =$					
$L =$					
L_1					
$L =$ given R	D	D	U	U	U
L regular	D	D	U	U	U
$L_1 \subseteq L_2$	D	U	U	U	U

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Here 'D' = decidable; 'U' = undecidable.

Proof Techniques for (Un-)Decidability

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Diagonalisation.

Reducti

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Simulation.

Exploitation of closure properties.

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Relevance of Computability Theory

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Knowing the limits of what can be done allows us to focus on decidable problems and functions that can be captured as algorithms.

It tells us to s against undecid

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For example, tools for software and protocol verifi izing compilers, and program repair are all based on approximations of programs' runtime states.

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The Last COMP30026 Slide!

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Phew... T https://eduassistpro.github.i

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