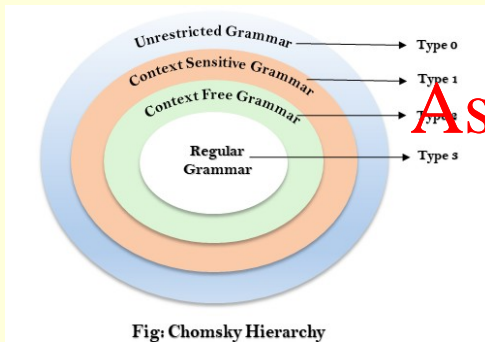


COSC1107 Computing Theory

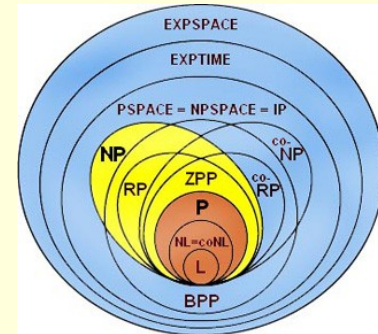
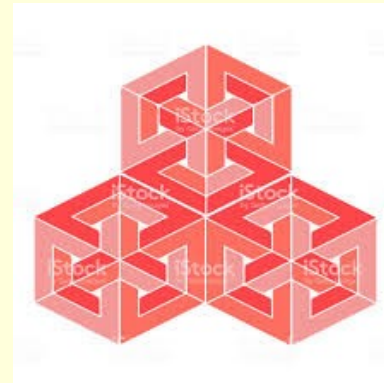
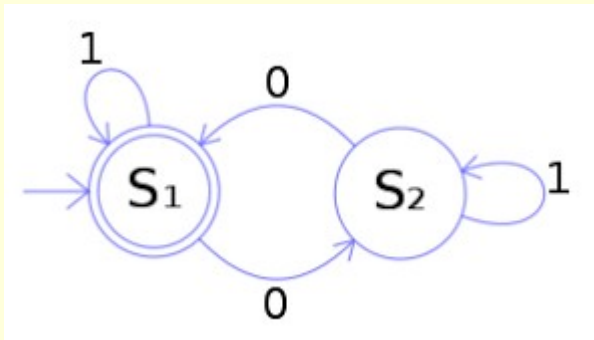
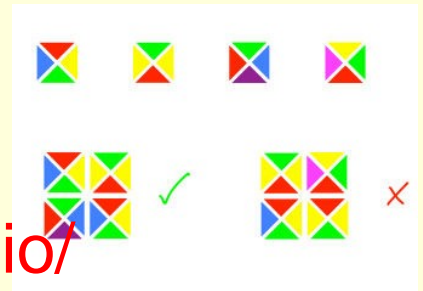
(We will commence soon. We are just allowing a few minutes for people to join and set up. *Please mute your microphone unless you are speaking.* You can raise your hand or use the chat at any time.)

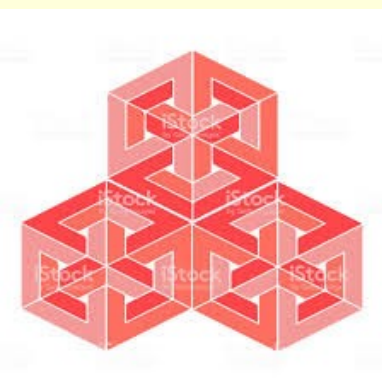
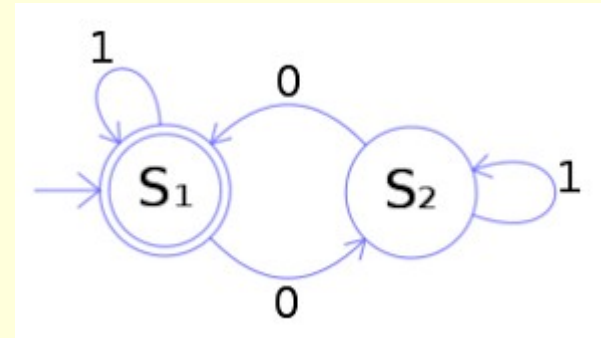
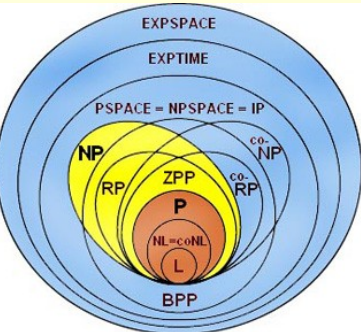


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COSC1107

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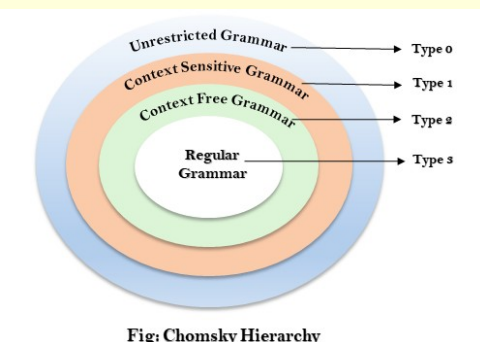
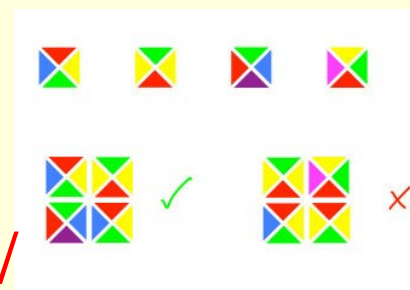


Fig: Chomsky Hierarchy

James Harland

james.harland@rmit.edu.au

* With thanks to Sebastian Sardina

Intro music 'Far Over' playing now ...



Week 3

Computing Theory

Acknowledgement



RMIT University acknowledges the people of the Woiwurrung and Boon wurrung language groups of the eastern Kulin Nations on whose unceded lands we conduct the business of RMIT University respectfully acknowledge Elders, past and present.

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RMIT also acknowledges the Traditional Custodians and their Ancestors of the lands and waters across Australia where we conduct our business.

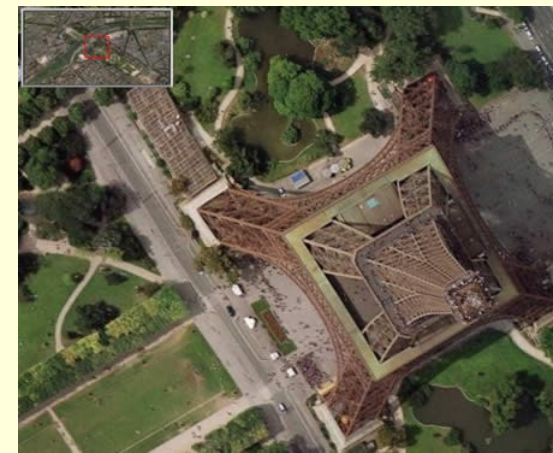
Overview

- Questions?
- Platypus Game
- Questions?
- Nondeterminis
- Questions?
- Pushdown Automata
- Questions?

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Questions?

Questions?



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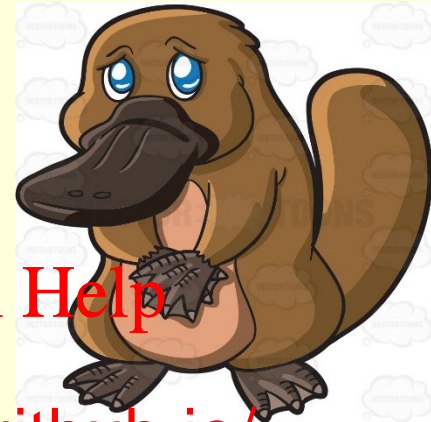
Questions?



The Platypus Game



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The Platypus Game



Get your 268-match tournament done soon!
Provides data on how many matches we can play

What should we do in Assignment 2? Help

Issues: <https://eduassistpro.github.io/>

1. How do we best approximate a full tournament?
(ie 268,435,456 machines)
2. What is the best scoring system?
3. Rule changes?
4. Other ideas?

The Platypus Game



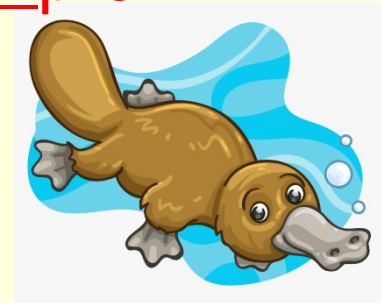
How do we best approximate a full tournament?
(ie 268,435,456 machines)

"Round robin + knockout"

- Play a full tournament with say 1,000 machines (~500,000 matches)
- Need around 268
- Knockout round with 10,000 matches)
- Around 134,000,
- Assignment 1 results will indicate this is
- Can play less than 1,000 if this is

"Champions League"

- Play as many (random) matches as possible
- Rank all machines via a ladder
- Top of the ladder at the end of the matches is the champion



The Platypus Game



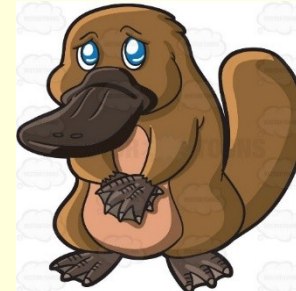
What is the best scoring system?

- More points for changing green to yellow than vice-versa
- Bonus or penalty scores for forfeiting the game
- Bonus or penalty
- Score multiplied
- Games run on more than one machine cells (all green, "chess like", random)
- Shortening or lengthening the number of turns before a game ends (currently 100)
- Tiebreaker?
- Other ideas?

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The Platypus Game



Rule changes?

- More players: 3? 4? 8? 10? ...
- Constrain machines (eg must contain at least two platypodes in row 4)
- Larger or small number of cells? (11? 31? 101?)
- Different rules for teaching a tree?
 - Bounce
 - Back to Billabong
- *More colours?*
- *More animals?*
- *2-dimensional board?*
- *Machine changes during play?*
- *NPCs?*

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Other ideas?

Survey will be used to determine assignment specification

Questions?

Questions?



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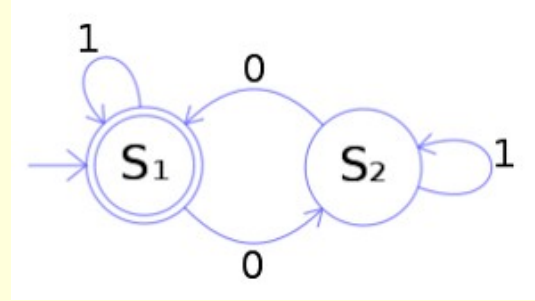
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Questions?



Review



Questions?

Last week:

- Finite State Automata
- Nondeterminism

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- What is the language
- Give a DFA/NFA for language

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```

graph LR
    Start(( )) --> S1(((S1)))
    S1 -- 1 --> S1
    S1 -- 0 --> S2((S2))
    S2 -- 0 --> S1
    S2 -- 1 --> S2
  
```

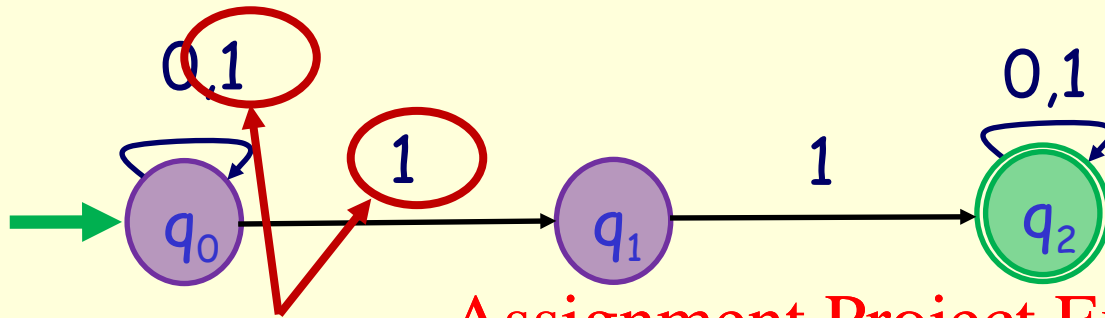
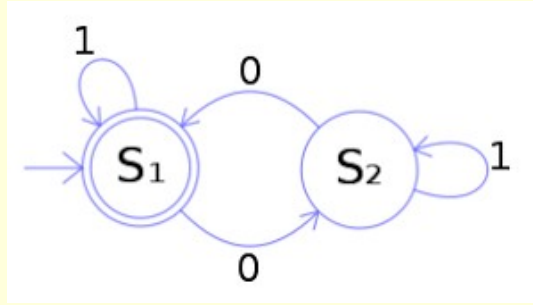
- Assignment Project Exam Help

[illegible]

Week 3

Computing Theory

Non-determinism



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You can't do that!

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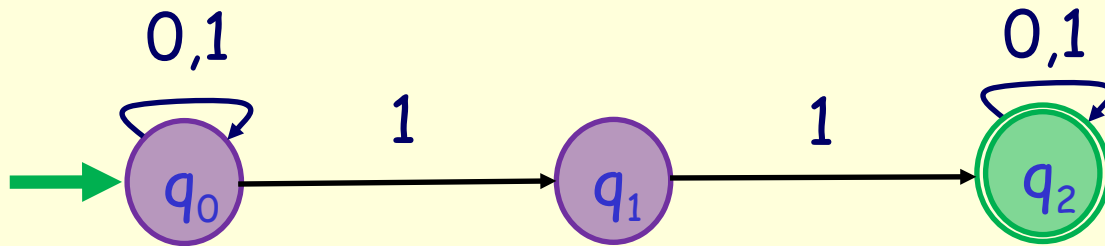
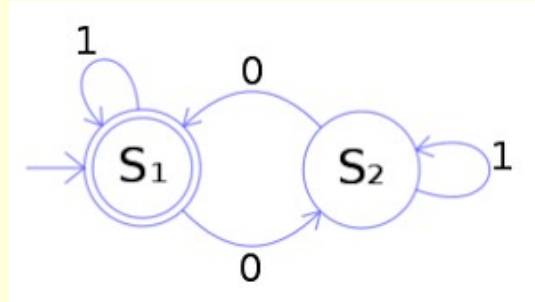
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$$L(M) = (0 \mid 1)^* 11 (0 \mid 1)^* = \{\text{strings containing } 11\}$$

Yes, you can, Sam ...

$$L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$$

Non-determinism



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Executions for 011:

$q_0 q_0 q_0$ no
 $q_0 q_0 q_1$ no
 $q_0 q_1 q_2$ yes

So 011 $L(M)$

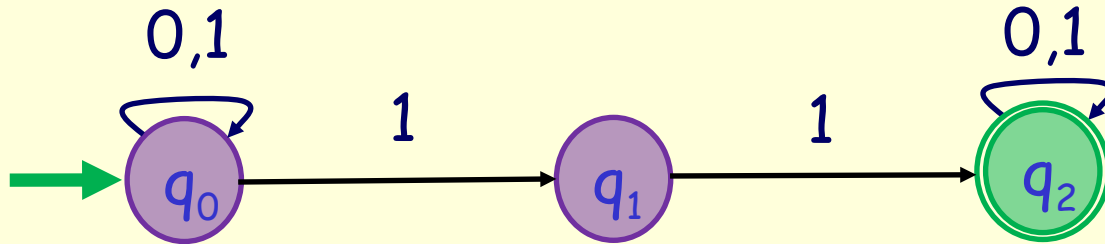
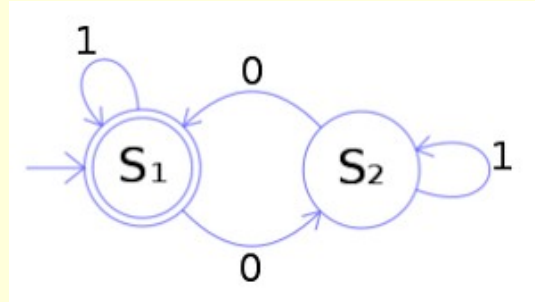
$L(M) = (0 \mid 1)^* 11 (0 \mid 1)^* = \{\text{strings containing } 11\}$
 $L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$

Executions for 1101:

$q_1 q_2 q_2 q_2$ yes
 $q_1 q_2 q_2 q_1$ no
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So 1101 $L(M)$

Non-determinism



Assignment Project Exam Help

Executions for 001:

$q_0 q_0 q_0$ no

$q_0 q_0 q_1$ no

So 001 $\notin L(M)$

Executions for 0101:

$q_0 q_1 q_0 q_1$ no
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So 0101 $\in L(M)$

"There is path 'via' w from the start state to a final state"
 $L(M) = (0|1)^*1(0|1)^* = \{\text{strings containing 1}\}$
 $L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$

[FSA5.jff](#)

Questions?

Questions?



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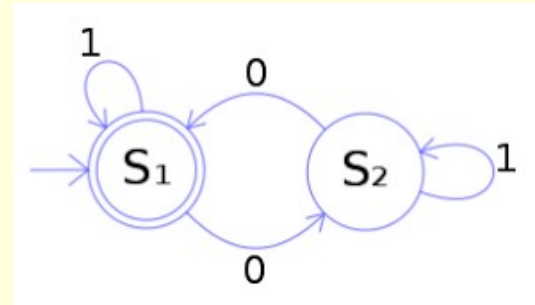
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Questions?



Formal Definition



A finite state automaton M is a 5-tuple (Q, δ, q_0, F)

- Q is a finite set of states
- δ is a finite mapping from $Q \times \Sigma$ to Q
- $Q \times Q$ is the transition relation
- q_0 is the start state
- $F \subseteq Q$ is the set of accepting or final states

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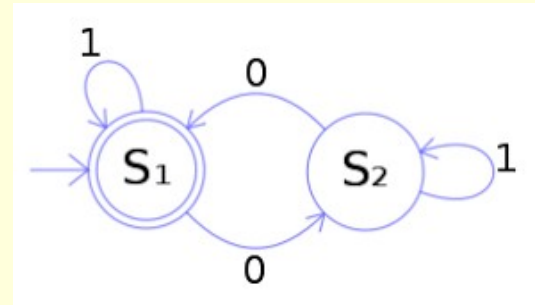
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Note:

- There is exactly one start state
- There can be many accepting states (can include the start state)

$$L(M) = \{w \mid M \text{ accepts } w \text{ (on some execution)}\}$$

Formal Definition



A **nondeterministic** finite state automaton M is a 5-tuple (Q, δ, q_0, F)

- Q is a finite set of **states**
- δ is a finite **alpha**
- $Q \times 2^Q$ is the **transition function**
- q_0 is the **start state**
- $F \subseteq Q$ is the set of **accepting states**

Note:

- There is exactly one **start state**
- There can be many **accepting states** (can include the start state)

$$L(M) = \{w \mid M \text{ accepts } w \text{ (on **some** execution)}\}$$

Questions?

Questions?



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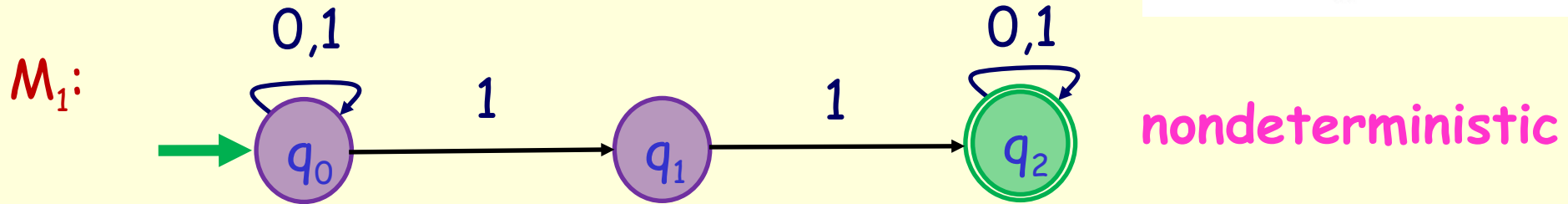
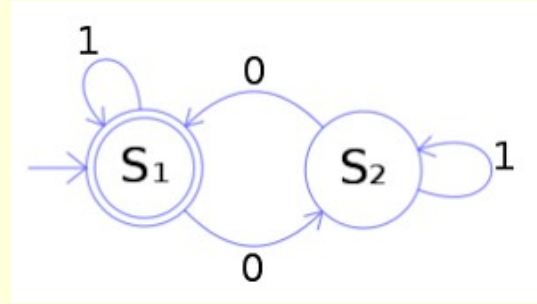
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Questions?



Non-determinism



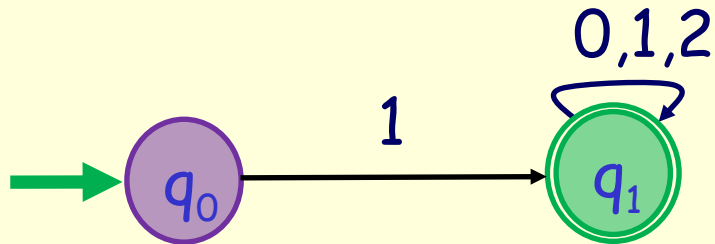
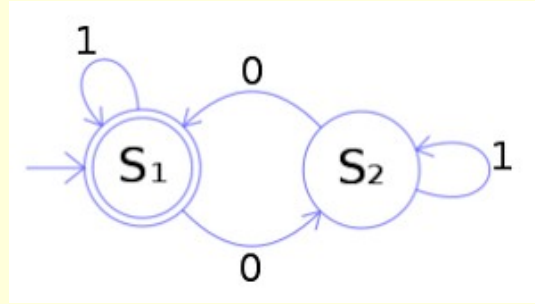
$L(M_1) = \{\text{strings containing } 11\}$



$L(M_2) = \{\text{strings containing } 11\} = L(M_1)$ so M_1 and M_2 are **equivalent**

Is there always an equivalent deterministic machine? **YES!**

Non-determinism

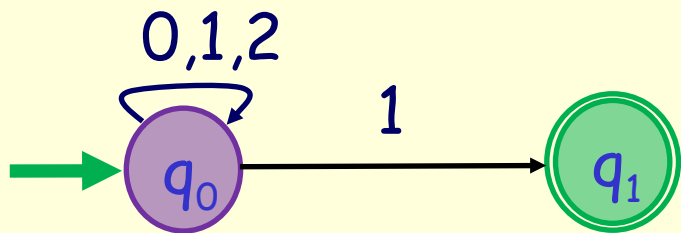


deterministic

$$L(M) = \{ \text{strings over } \{0,1,2\} \\ \text{starting with } 1 \} \\ = 1(0 \mid 1 \mid 2)^*$$

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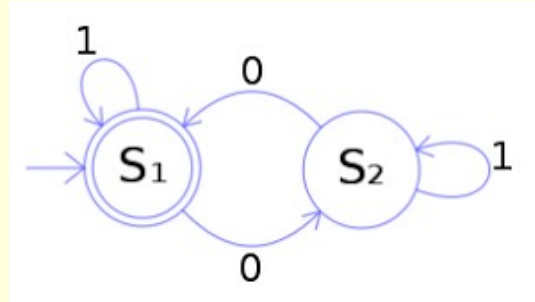
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nondeterministic

$$L(M) = \{ \text{strings over } \{0,1,2\} \\ \text{ending with } 1 \} \\ = (0 \mid 1 \mid 2)^* 1$$

Limits of FSAs

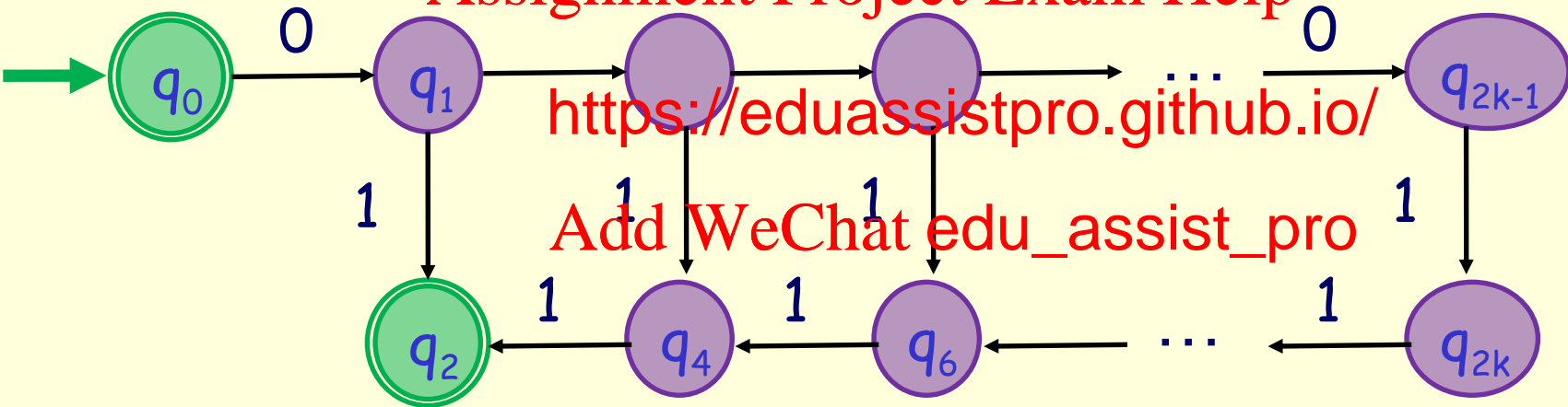


Give an FSA for the language $L = \{0^n 1^n \mid n \geq 0\}$
 $L = \{, 01, 0011, 000111, 00001111, 0000011111, \dots\}$

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$L = \{0^n 1^n \mid n \leq k\} = \{, 01, 0011, 000111, \dots, 0^k 1^k\}$

Questions?

Questions?



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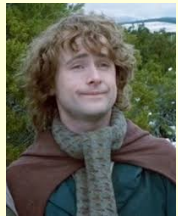
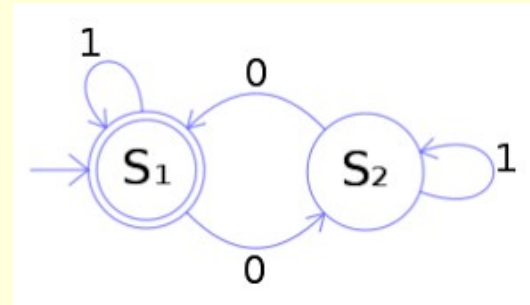
Questions?



Pushdown Automata



What do computers do again?



- Input and output
- Processing
- Memory

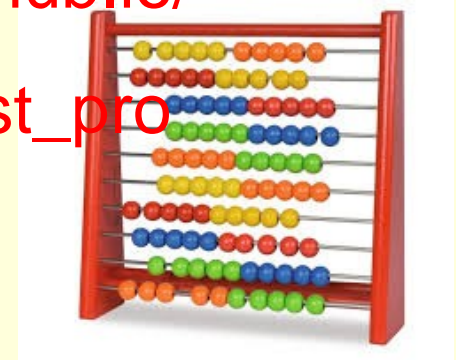
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What is the next <https://eduassistpro.github.io/>

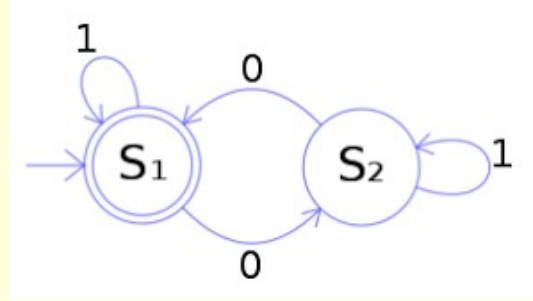
- **Input:** a string
- **Output:** yes or no (decision problem)
- **Memory:** a fixed amount
- **Processing:** changes between a finite number of states

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Memory has the biggest effect, so ...

Brackets



Do the brackets balance?

((() (())) ())

YES

1 2 3 2 3 4 5 4 3 2 1 0

(((((()) https://eduassistpro.github.io/

1 2 3 4 5 6 5 4 3 2 3 2 1 0

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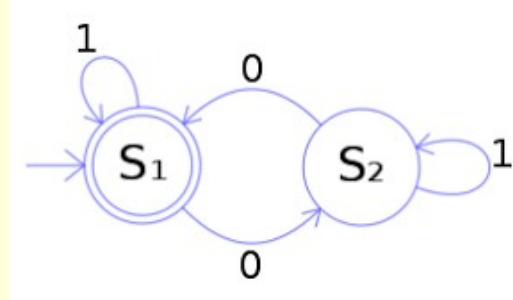
((() ((())))) (

1 2 3 2 3 4 5 4 3 2 1 0 -1 0 (!!)

NO

$L = \{ \text{strings over } \{ (,) \} \text{ with balanced brackets} \}$

Brackets



$L = \{ \text{strings over } \{ (,) \} \text{ with balanced brackets} \}$

Algorithm to recognise L :

- Count the brackets from left to right
- +1 for each (
- 1 for each)
- If the count reach
- Accept if the count is 0 at the end

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Add WeChat edu_assist_pro (else "too many ('s")



What if there are multiple kinds of brackets ([{ ??

(({ } [])) yes
(({ [] })) no

(think HTML ...)

Here we need to store the **sequence**, not just the count

Pushdown Automata



PSA = FSA + stack

Stack

- linear sequence of items
- Last in first out (LIFO)
- Only two operations
- **Push:** put an item
- **Pop:** take the top item off the (non-empty) stack
- Often used in implementations of recursive calls

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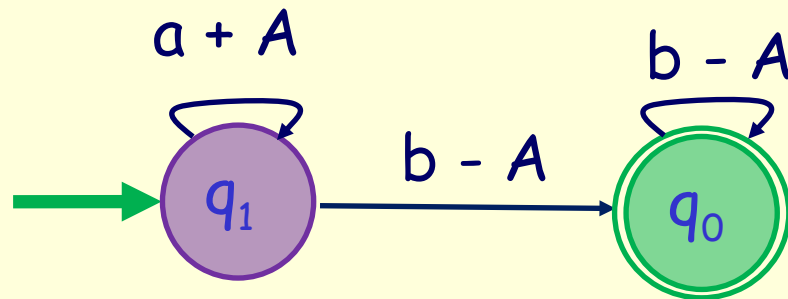
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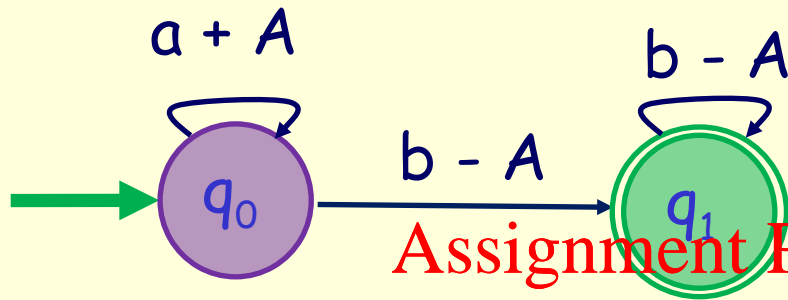
Pushdown Automata



- Stack operations:
 - Push** a single item onto the top of the stack
 - Pop** the top item off the top of the stack
- Stack is **initially empty**
- String is **accepted** if execution finishes in an accepting state **AND** the stack is
- String is rejected
 - Execution finish
 - Empty stack is popped
 - Stack not empty at end
 - Execution finishes in a non-accepting state



Pushdown Automata

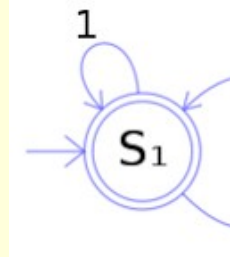


Assignment Project Exam Help

Input: aaabbb

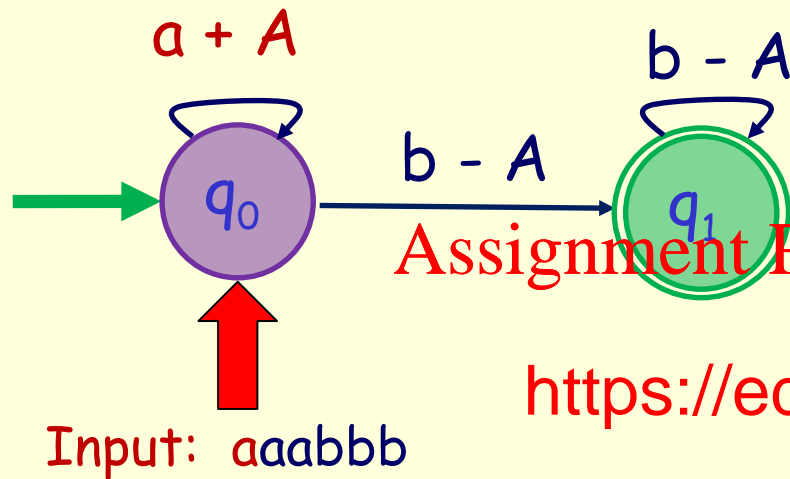
<https://eduassistpro.github.io/>
ack

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Pushdown Automata

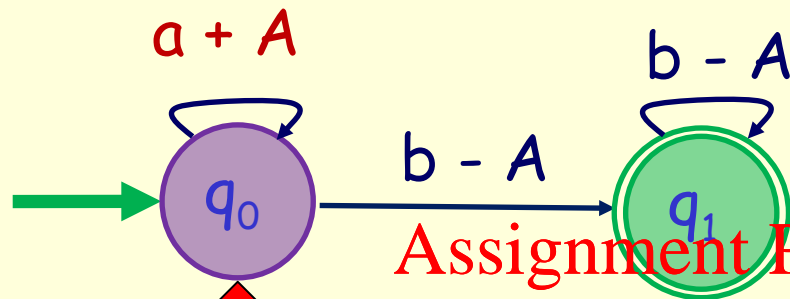


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ack](https://eduassistpro.github.io/ack)

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Pushdown Automata



Input: aaabbb

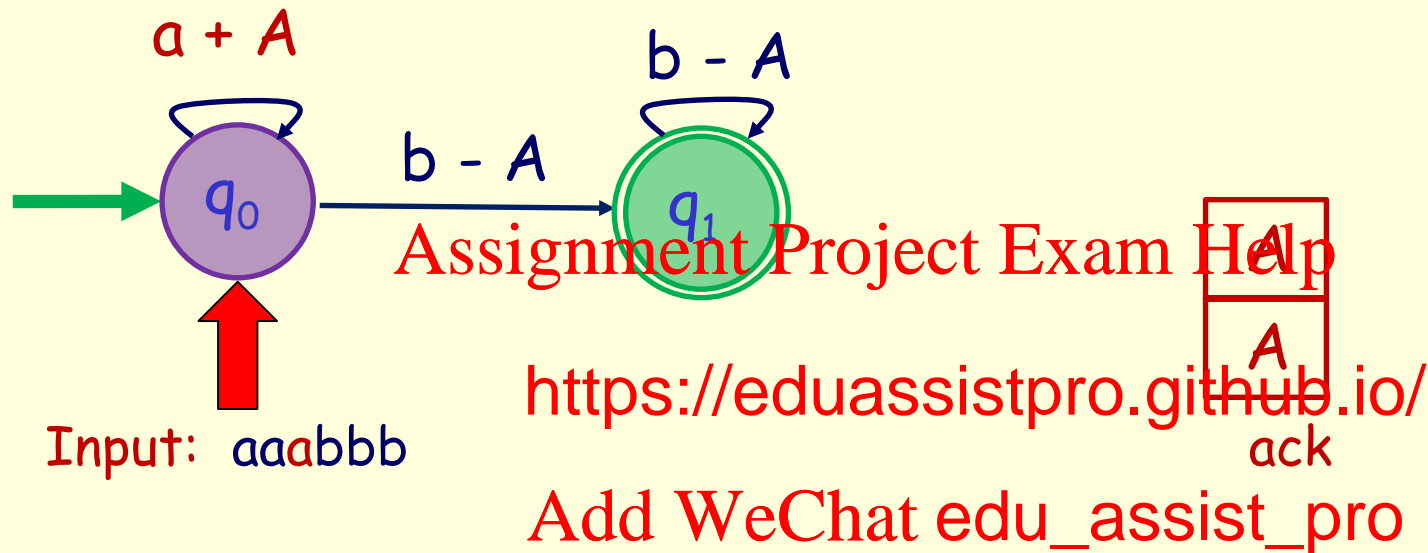
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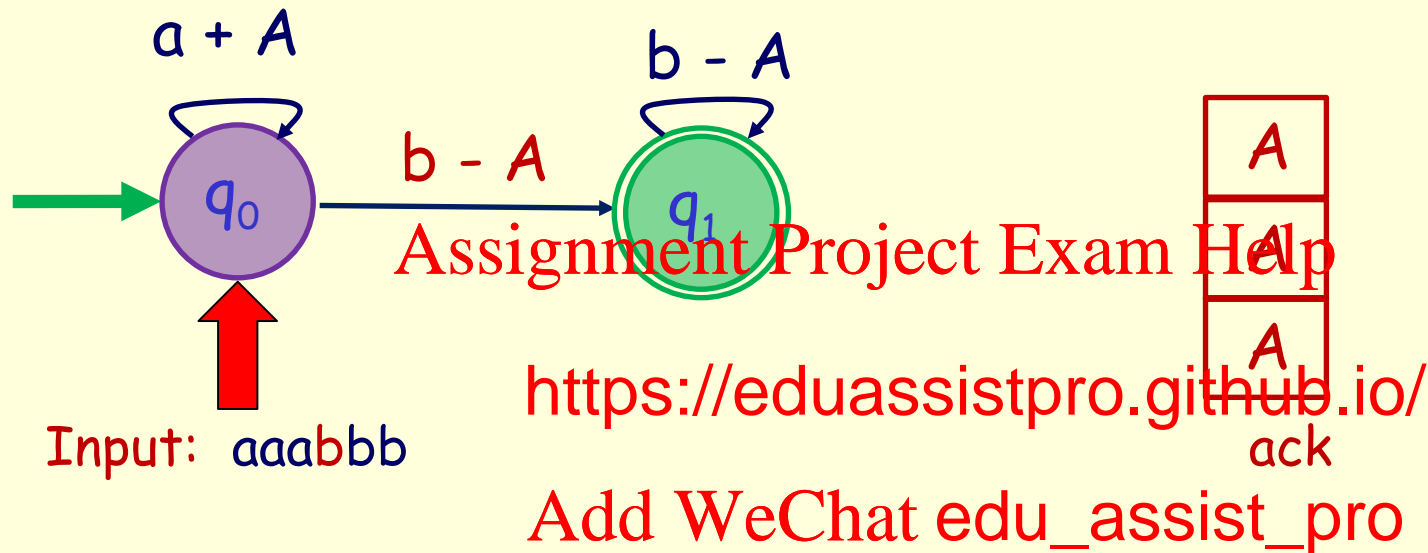
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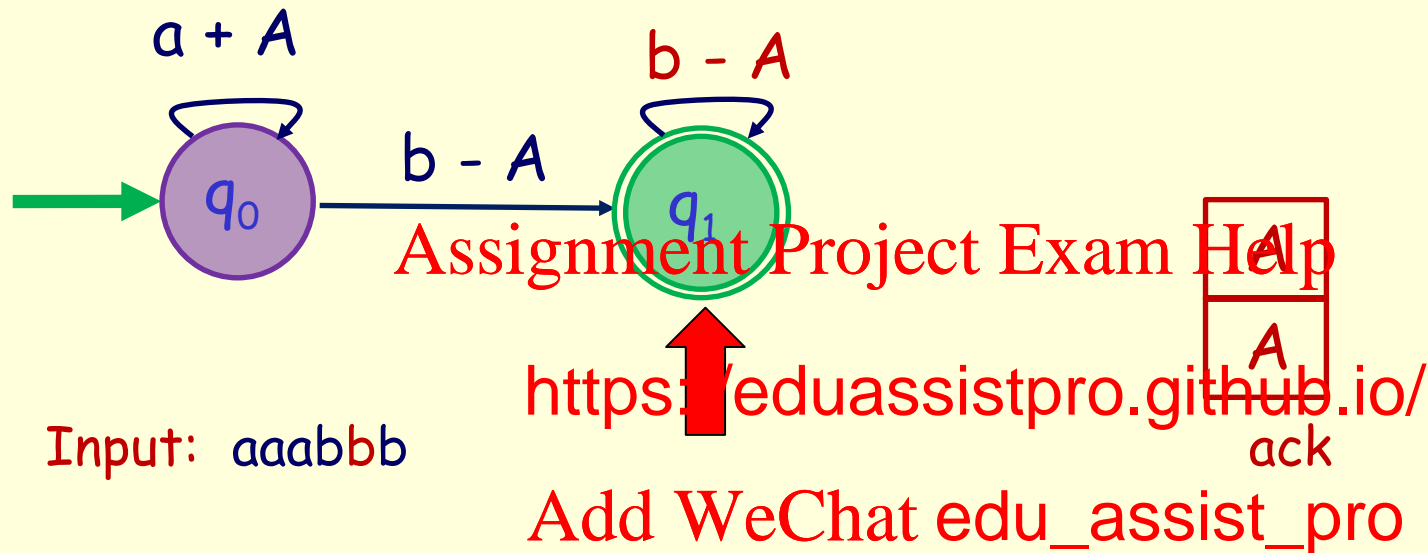
Pushdown Automata



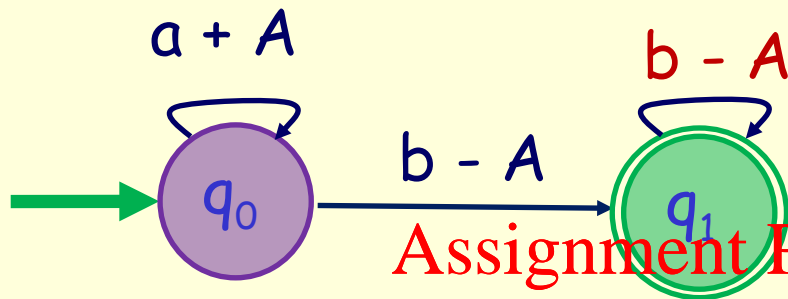
Pushdown Automata



Pushdown Automata



Pushdown Automata



Assignment Project Exam Help

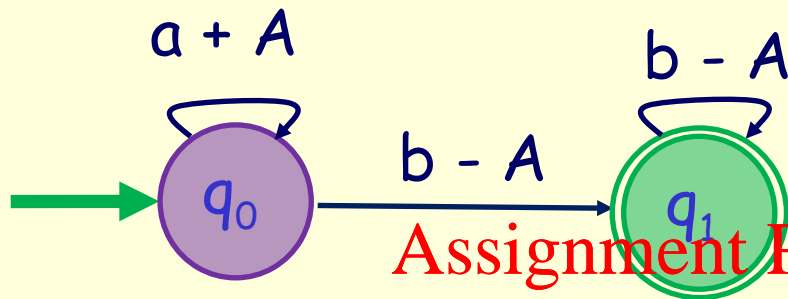
Input: aaabbb

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A
ack

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Pushdown Automata



ACCEPTED!

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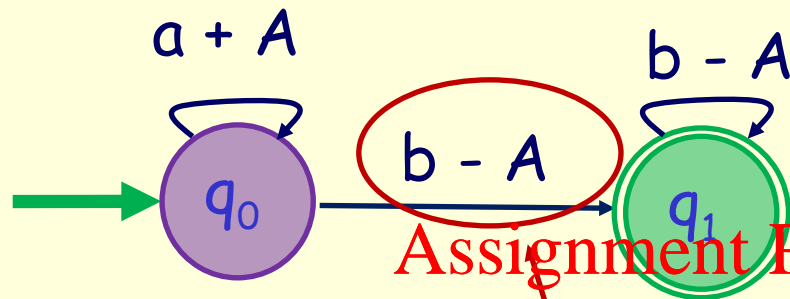
Input: aaabbb

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PDA1.jff



Pushdown Automata



REJECTED!

Input: aaabb

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Add "WeChat" edu_assist_pro

A
ack

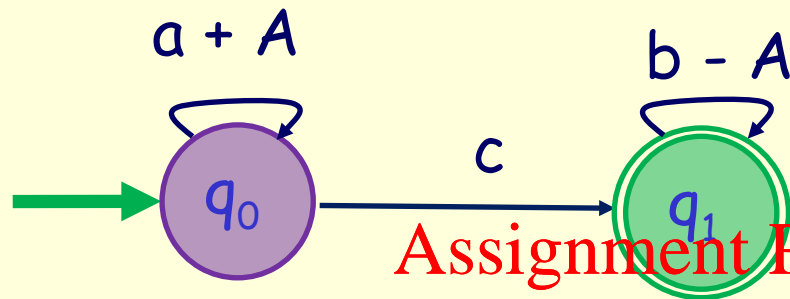
$L(M) = ??$

$L(M) = \{a^n b^n \mid n \geq 1\} ??$



Key Idea: How could the stack be emptied?

Pushdown Automata



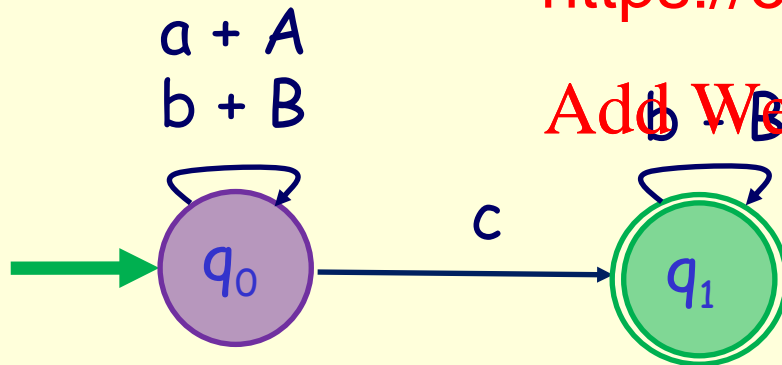
$L(M) = ??$

[PDA2.jff](#)

Assignment Project Exam Help $L(M) = \{a^n b^n \mid n \geq 0\}$

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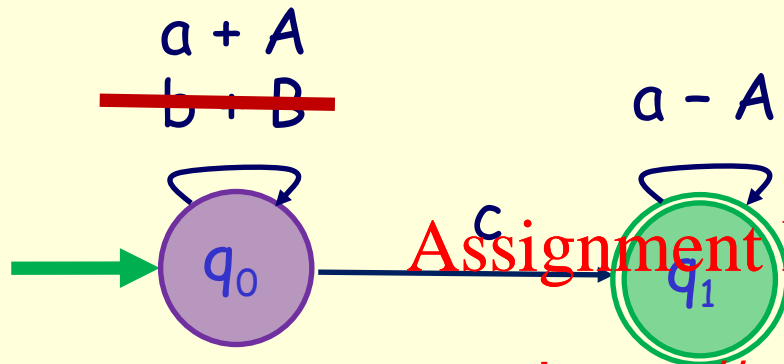


[PDA3.jff](#)

$L(M) = \{wcw^R \mid w \text{ is a string over } \{a,b\}\}$

(w^R is the reverse of the string w)

Pushdown Automata



$L(M) = ??$

[PDA4.jff](#)

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Key Idea: How the stack behaves

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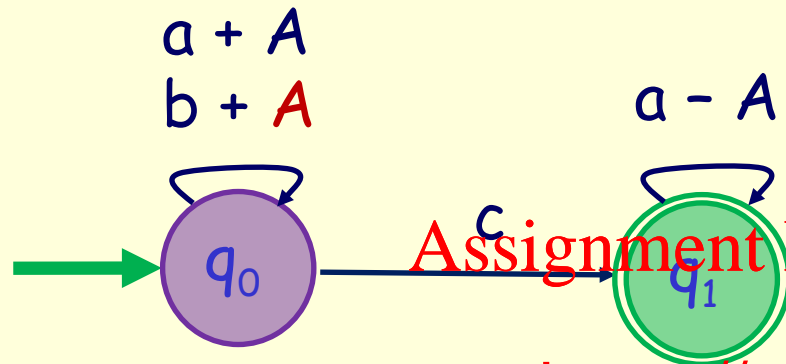
In: $c, aca, aacaa, aaacaaa, \dots$

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Out: $ac, bca, abcaa, bbacaaa, c$

$$L(M) = \{a^n c a^n \mid n \geq 0\}$$

Pushdown Automata



$L(M) = ??$

PDA5.jff

Assignment Project Exam Help

Key Idea: How the stack be
ie

<https://eduassistpro.github.io/>

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In: $c, bca, aacaa, abbcaga, \dots$

Out: $ac, bbca, abcb, bbacaaaa, \dots$

$$L(M) = \{ wca^n \mid w \{a,b\}^*, |w| = n \}$$



Quiz time!

Go to **Canvas** and find the quiz **Lectorial 3 Quiz**

- Not worth any marks
- Middle "question" will require some thinking - you can consult other students if you wish
- Time limit will be <https://eduassistpro.github.io/>

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Are you ready?

Are you sure?

Go!

The pictures will take 10 minutes to disappear!

Thomas music means 1 minute left!



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Questions?

Questions?



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Questions?





twinkl.com



How did you go?

Question 1: Which of the following statements are correct?

- Pushdown automata are named after Penelope Pushdown. **FALSE**
- Pushdown automata add a queue to finite state automata. **FALSE**
- Pushdown automata automata. **FALSE**
- Pushdown automata automata. **True**
- Pushdown automata add two stacks e automata. **FALSE**
- A string is accepted by a pushdown execution finishes in an accepting state AND the stack is empty. **True**
- A string is accepted by a pushdown automaton if execution finishes in an accepting state OR the stack is empty. **FALSE**

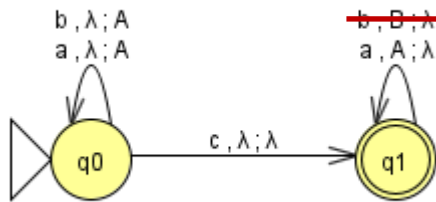
How did you go?



twinkl.com

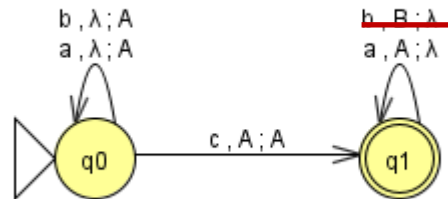


Question 2: What languages are accepted by the following machines?

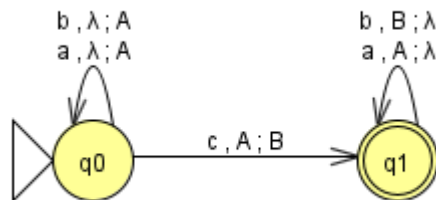


Assignment Project Exam Help
 $L_1 = \{wca \mid w \in \{a,b\}^*, |w| = n\}$

<https://eduassistpro.github.io/>



Add WeChat $L_2 = \{wca \mid w \in \{a,b\}^*, |w| = n, n \geq 1\}$



$L_3 = \{wcba^{n-1} \mid w \in \{a,b\}^*, |w| = n, n \geq 1\}$

Computing Theory

FSA vs PDA

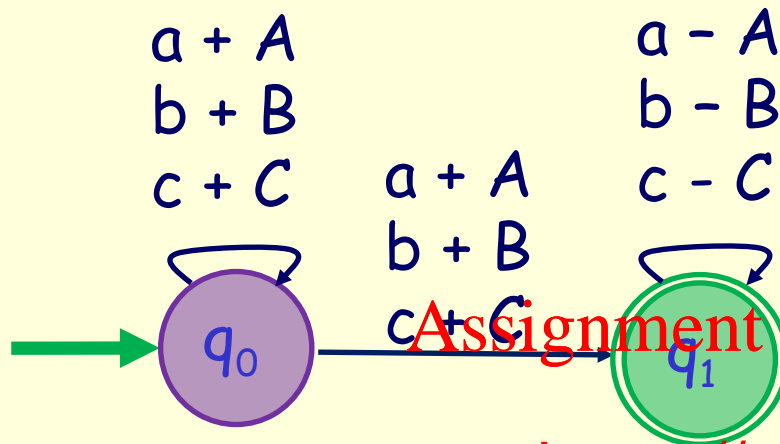


	FSA	PDA
Input	String	String
Output	Yes or no	Yes or no
Processing	One sym right	* symbol at a time, left to right
Memory	Current state	state + stack
Acceptance	Final state	ate + empty stack
Non-determinism?	Yes	Yes

*Some PDAs allow multiple symbols at a time, either as input or as stack operations (push, pop). This makes no overall difference.

PDAs can also have "extra" stack symbols not in the input language (Z in JFLAP for instance)

Pushdown Automata



$L(M) = ??$

PDA6.jff

Assignment Project Exam Help

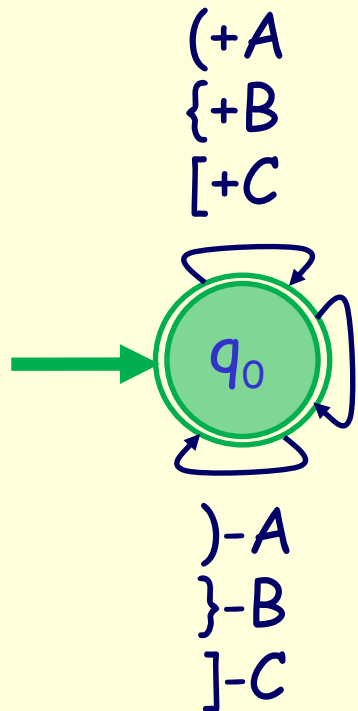
<https://eduassistpro.github.io/>

In: cc, bbbb, abba, bccb, abc, bcb...

Out: ac, bbca, abcb, bbacaaaa,

$$L(M) = \{ w \mid w \{a,b,c\}^+, |w| = 2n, w = w^R \}$$

Pushdown Automata



$L(M) = ??$ PDA7.jff

~~x.y.z~~ Assignment Project Exam Help

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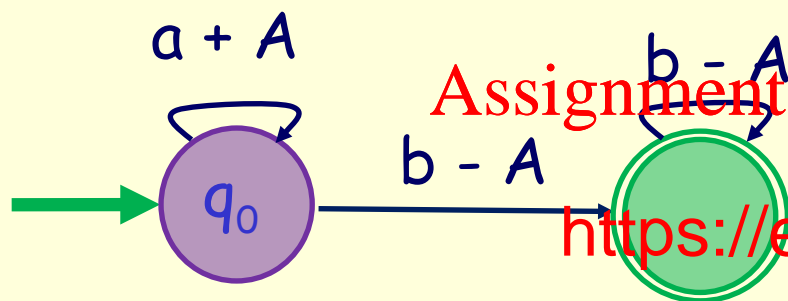
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$L(M) = \{ w \mid w \text{ has balanced brackets} \}$

PDAs in JFLAP

JFLAP does PDAs a little differently ...

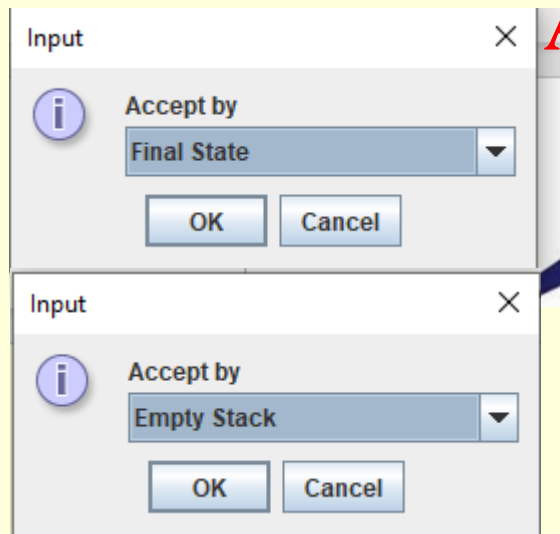
- JFLAP allows multiple inputs per transition
- JFLAP accepts via final state OR empty stack (!!)



Assignment Project Exam Help

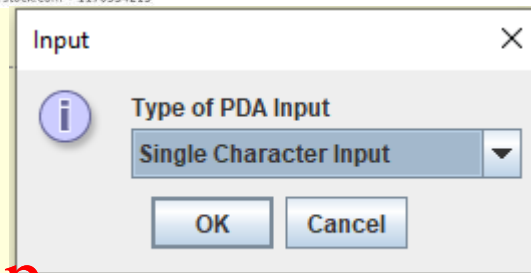
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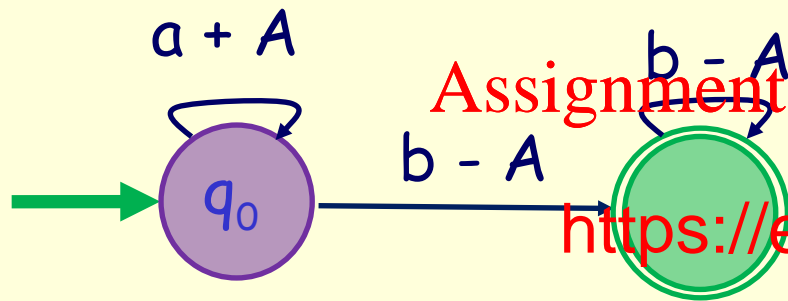
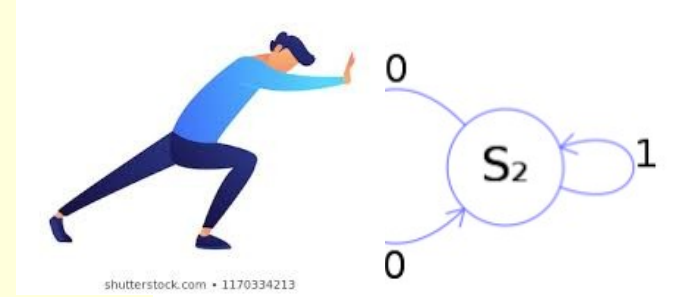
Week 3

Compu



PDAs in JFLAP

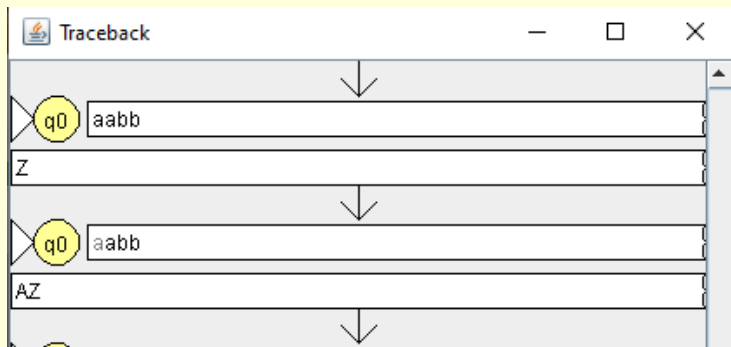
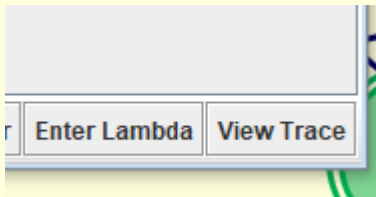
JFLAP does PDAs a little differently ...



Assignment Project Exam Help

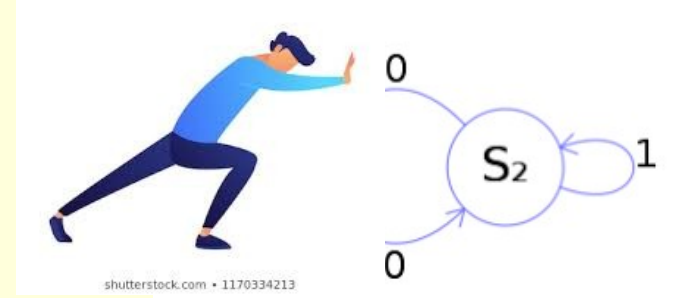
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Computing Theory

JFLAP for grammars

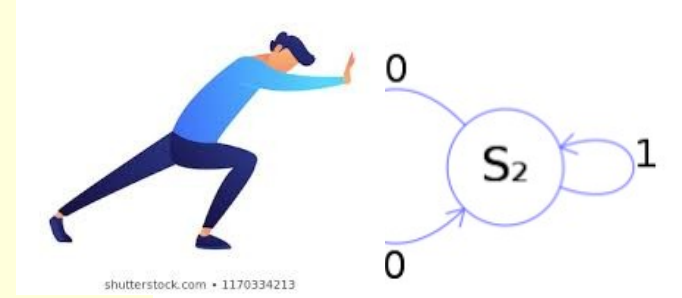


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JFLAP



JFLAP is your friend!

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Questions?

Questions?



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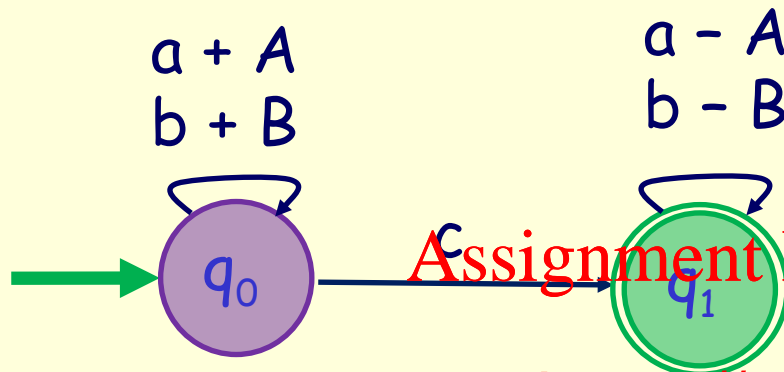
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Questions?



Pushdown Automata



$L(M) = ??$

PDA8.jff

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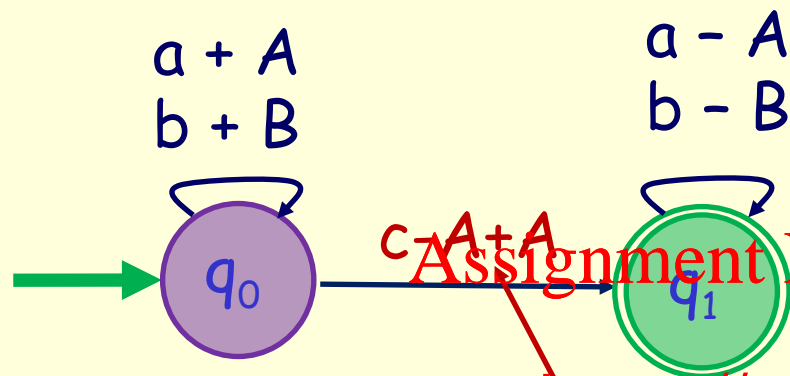
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$$L(M) = \{ wcw^R \mid w \{a,b\}^* \}$$

Pushdown Automata



$L(M) = \dots$



Input: bbacabb

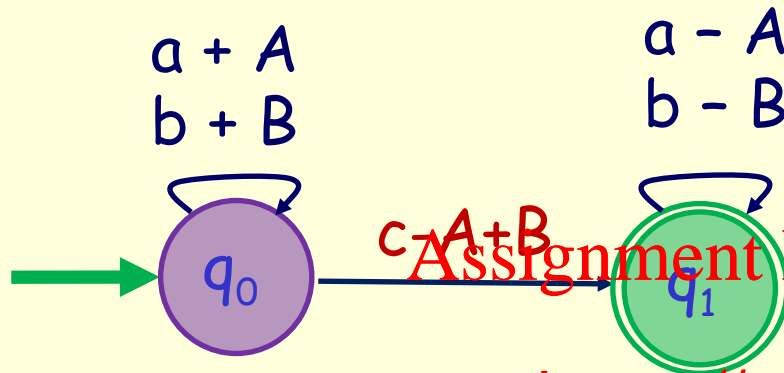
'only transition if there is an A otherwise reject'.



PDA9.jff

$$L(M) = \{ wacaw^R \mid w \{a,b\}^* \}$$

Pushdown Automata



$L(M) = ??$

[PDA10.jff](#)

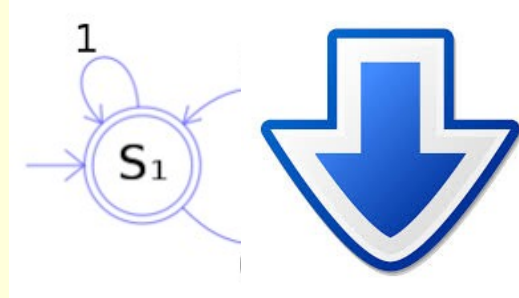
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Can you work out $L(M)$?

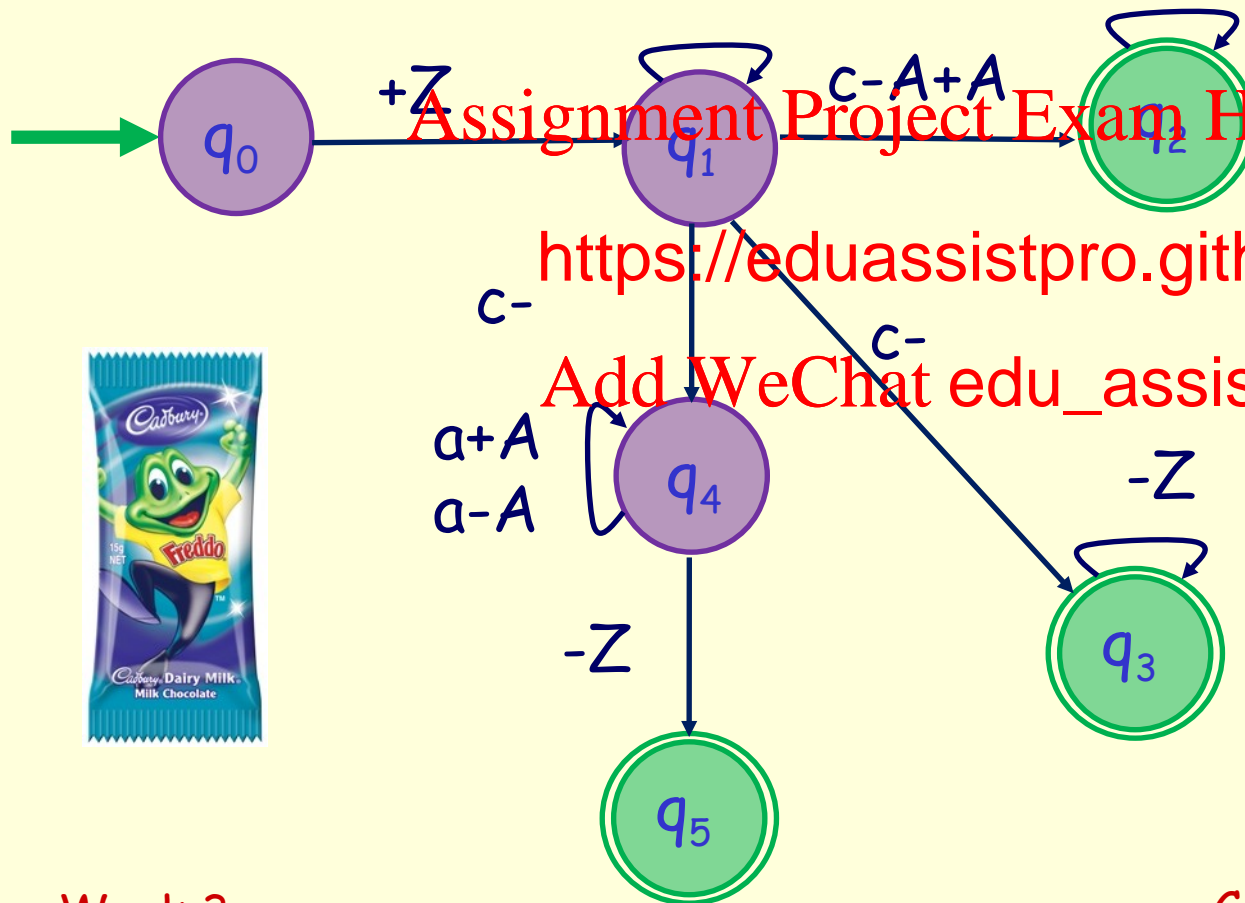
Pushdown Automata



$a + A$
 $b + B$

$a - A$
 $b - B$
 $-Z$

$L(M) = ??$



Assignment Project Exam Help

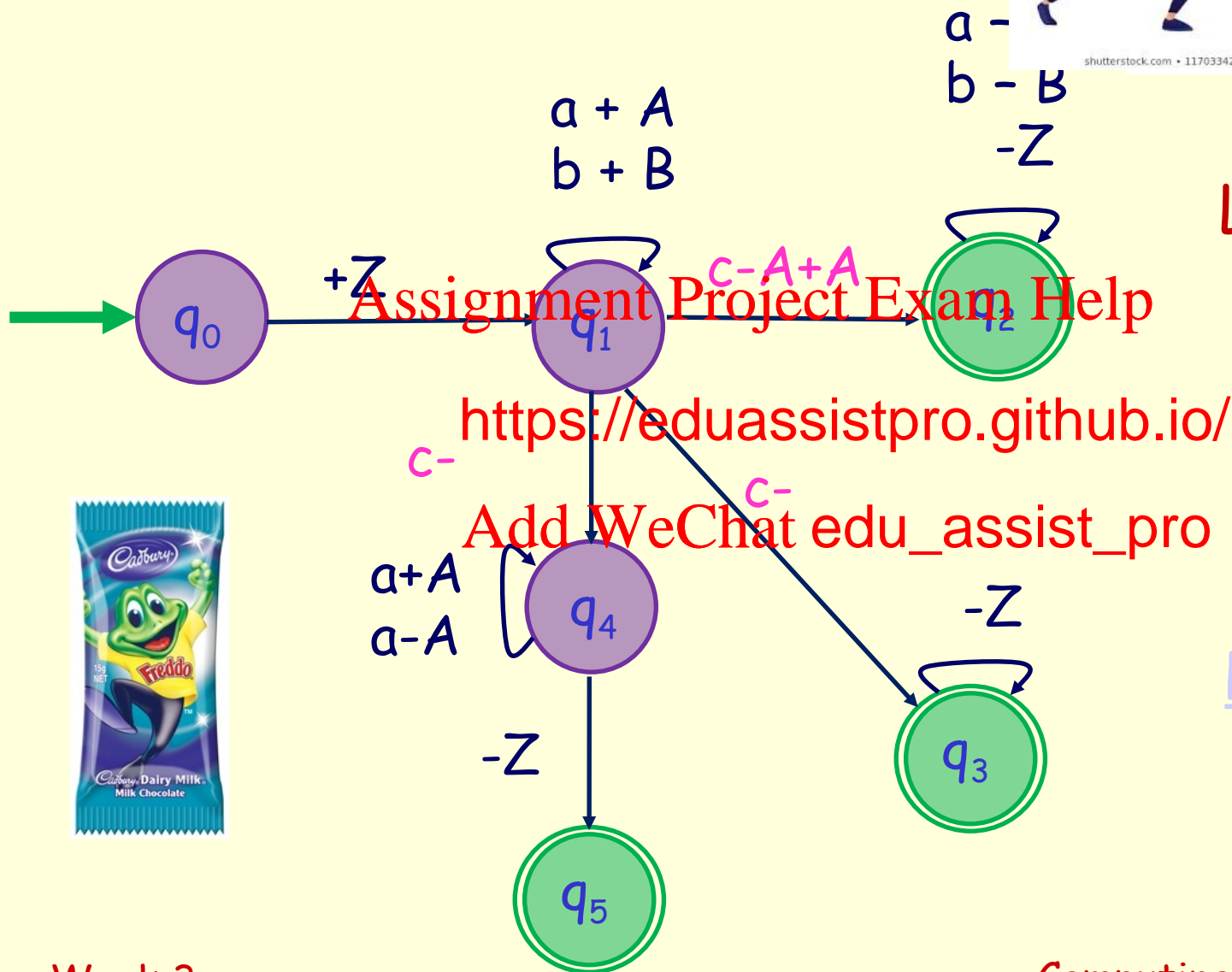
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PDA11.jff

Pushdown Automata

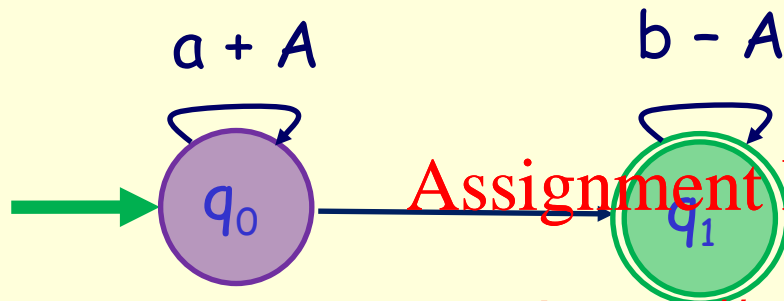


$L(M) = ??$



PDA11.jff

Pushdown Automata



$L(M) = ??$

[PDA12.jff](#)

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$$L(M) = \{a^n b^n \mid n \geq 0\}$$

What about $L = \{a^n b^n c^n \mid n \geq 0\}$?

Questions?

Questions?



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Questions?



That's it!



I am out of here!

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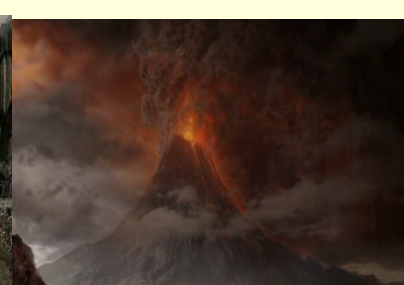
Break time! (We resume when all the pictures are gone! This will take 3 minutes!)



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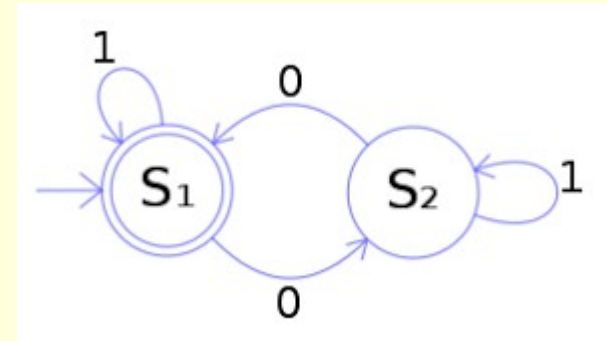
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I AM BACK!

Marking

Computing Theory

Marking



Why did I lose marks for ...??



Where did you last see them?
Assignment Project Exam Help

At <https://eduassistpro.github.io/>

Perhaps you should add WeChat [edu_assist_pro](#) in at night ...

Never feed them after midnight!

...

Alternative Scheme?



Troll	Dreadful	Poor	Acceptable	Exceeds Expectations	Outstanding
-------	----------	------	------------	----------------------	-------------

Outstanding - CONGRATULATIONS! Your exemplary powers of deduction and a formidable knowledge of the inner workings of the magical world reveal you to be a witch or wizard of genuine skill and learning.

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Exceeds Expectations - performance!

Acceptable - demonstrated <https://eduassistpro.github.io/>

Poor - Alas - we regret to inform you that you have failed. This may have been due to factors outside your control (eg: poltergeist attack, examination nerves or a malfunctioning quill.) Please do not disconsolate.

Dreadful - We are sorry to inform you that you have failed.

Troll - You would appear either to have abandoned the test due to factors outside your control (eg, earthquake, poltergeist attack), or else you are a troll, in which case you are to be congratulated on being able to use a computer and have achieved the grade of O.F.T. (Outstanding for Trolls).

Marking

Computing Theory

Alternative Scheme?



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-------	----------	------	------------	----------------------	-------------

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Marking

Computing Theory