61A Extra Lecture 4

Announcements

Encoding Strings

Representing Strings: UTF-8 Encoding

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`UTF (UCS (Universal Character Set) Transformation Format)`

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A byte is 8 bits and can encode any integer 0-255.

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Variable-length encoding: integers vary in the number of bytes required to encode them.

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In Python: string length is measured in characters, bytes length in bytes.

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Variable-length encoding: integers vary in the number of bytes required to encode them.

In Python: string length is measured in characters, bytes length in bytes.

(Demo)

Fixed-Length Encodings

A First Attempt

A First Attempt

- Let’s use an encoding

A First Attempt

- Let’s use an encoding

Letter	Binary	Letter	Binary
a	0	n	1
b	1	o	0
c	0	p	1
d	1	q	1
e	1	r	0
f	0	s	1
g	0	t	0
h	1	u	0
i	1	v	1
j	1	w	1
k	0	x	1
l	1	y	0
m	1	z	0

Decoding

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- How many bits do we need to encode each letter uniquely?

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  - lowercase alphabet

Decoding

- An encoding without a deterministic decoding procedure is not very useful
- How many bits do we need to encode each letter uniquely?
  - lowercase alphabet
  - 5 bits

A Second Attempt

A Second Attempt

- Let’s try another encoding

A Second Attempt

- Let's try another encoding

Letter	Binary	Letter	Binary
a	00000	n	01101
b	00001	o	01110
c	00010	p	01111
d	00011	q	10000
e	00100	r	10001
f	00101	s	10010
g	00110	t	10011
h	00111	u	10100
i	01000	v	10101
j	01001	w	10110
k	01010	x	10111
l	01011	y	11000
m	01100	z	11001

Analysis

Analysis

Pros

Analysis

Pros

- Encoding was easy

Analysis

Pros

- Encoding was easy
- Decoding was deterministic

Analysis

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Cons

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- Takes more space…

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- What restriction did we place that’s unnecessary?

Analysis

Pros

- Encoding was easy
- Decoding was deterministic

Cons

- Takes more space…

- What restriction did we place that’s unnecessary?
    - Fixed length

Variable-Length Encodings

Variable Length Encoding

Variable Length Encoding

- `Encoding Candidate 1: A: 1, B:01, C: 10, D: 11, E: 100, F: 101, ...`

Variable Length Encoding

- Encoding Candidate 1: A: 1, B:01, C: 10, D: 11, E: 100, F: 101, ...
  - What does 01111 encode?

Variable Length Encoding

- `Encoding Candidate 1: A: 1, B:01, C: 10, D: 11, E: 100, F: 101, ...`
    - `What does 01111 encode?`
- `Encoding Candidate 2: A: 00, B: 01, C: 100, D: 101, E: 1100, F: 1101, ...`

Variable Length Encoding

- Encoding Candidate 1: A: 1, B:01, C: 10, D: 11, E: 100, F: 101, ...
  - What does 01111 encode?
- Encoding Candidate 2: A: 00, B: 01, C: 100, D: 101, E: 1100, F: 1101, ...
  - What does 0100101 encode? How about 10111001101001001100?

Variable Length Encoding

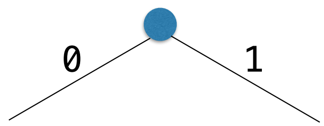
- Encoding Candidate 1: A: 1, B:01, C: 10, D: 11, E: 100, F: 101, **...**
    - What does 01111 encode?
- Encoding Candidate 2: A: 00, B: 01, C: 100, D: 101, E: 1100, F: 1101, **...**
    - What does 0100101 encode? How about 10111001101001001100?
- Deterministic decoding from left to right is possible if the encoding of one character is **never** a proper prefix of the decoding of another character.

Deterministic Codes Have a Tree Structure

Deterministic Codes Have a Tree Structure

Letter	Binary
A	00
B	01
C	1

Deterministic Codes Have a Tree Structure



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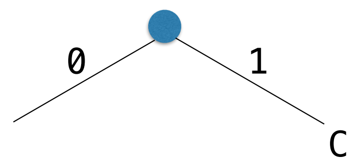

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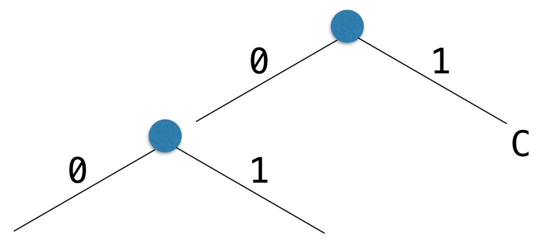

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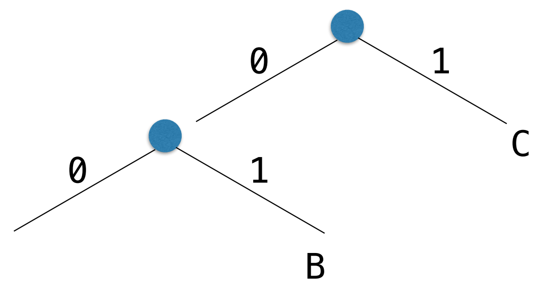

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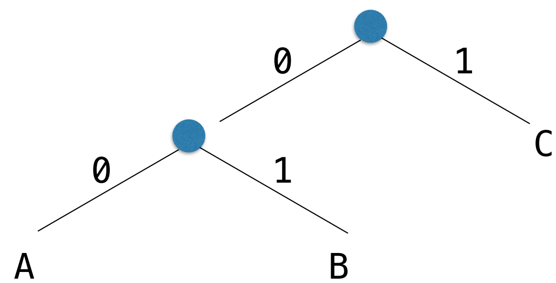

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Huffman Encoding

Huffman Encoding

- Let’s pretend we want to come up with the optimal encoding:

Huffman Encoding

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  - AAAAAAAAAABBBBBCCCCCCDDDDDDDDDD

Huffman Encoding

- Let’s pretend we want to come up with the optimal encoding:
    - AAAAAAAAAABBBBBCCCCCCDDDDDDDDDD
    - A appears 10 times

Huffman Encoding

- Let’s pretend we want to come up with the optimal encoding:
  - AAAAAAAAAABBBBBCCCCCCCDDDDDDDDD
  - A appears 10 times
  - B appears 5 times

Huffman Encoding

- Let’s pretend we want to come up with the optimal encoding:
    - AAAAAAAAAABBBBBCCCCCCCDDDDDDDDDD
    - A appears 10 times
    - B appears 5 times
    - C appears 7 times

Huffman Encoding

- Let’s pretend we want to come up with the optimal encoding:
    - AAAAAAAAAABBBBBCCCCCCCDDDDDDDDD
    - A appears 10 times
    - B appears 5 times
    - C appears 7 times
    - D appears 9 times

Huffman Encoding

Huffman Encoding

- Start with the two smallest frequencies

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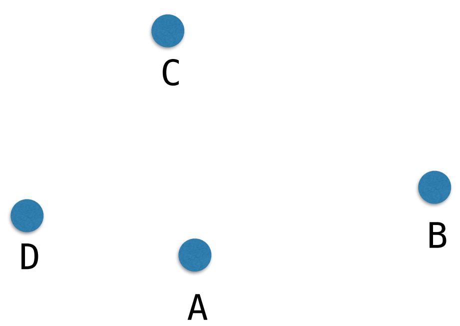

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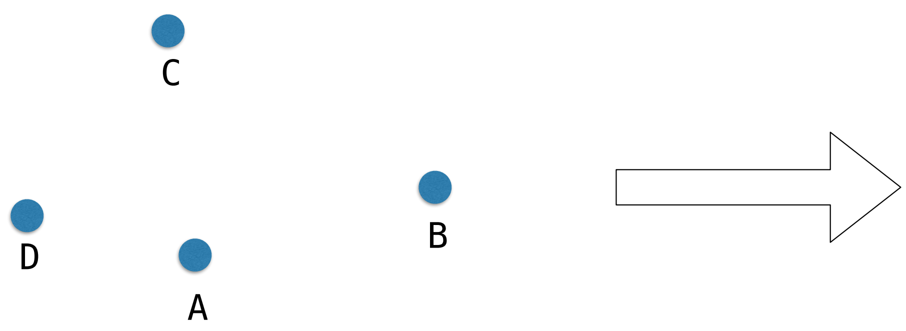

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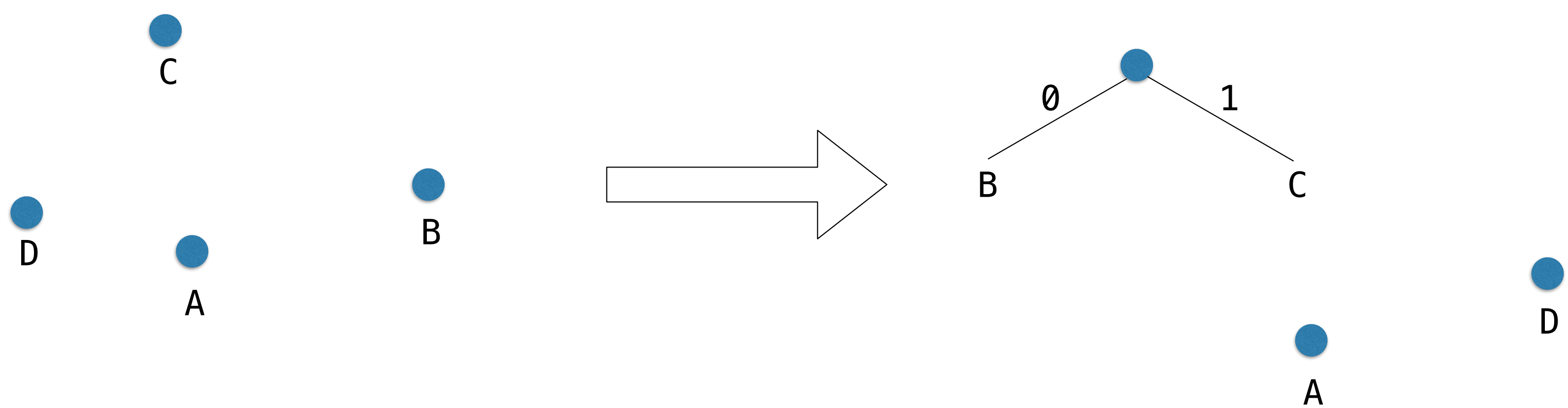

Huffman Encoding

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- Continue…

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  - A appears 10 times, B & C appear a combined 12 times, D appears 9 times

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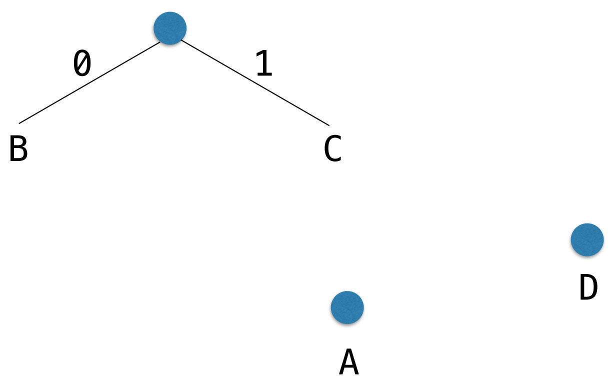

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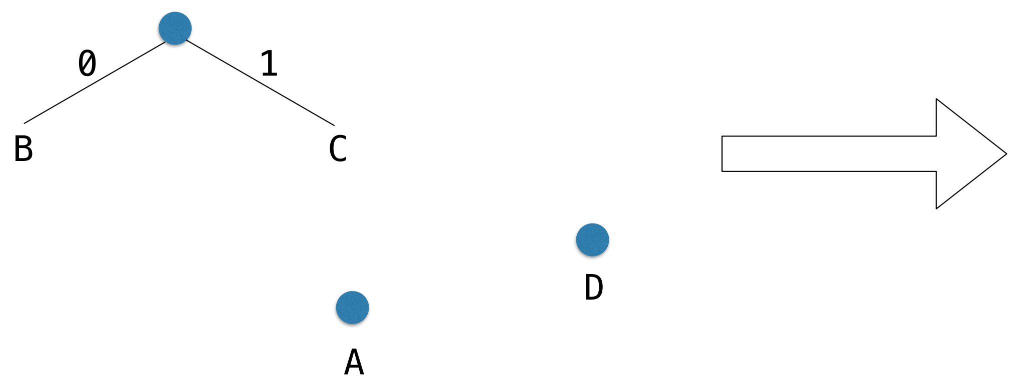

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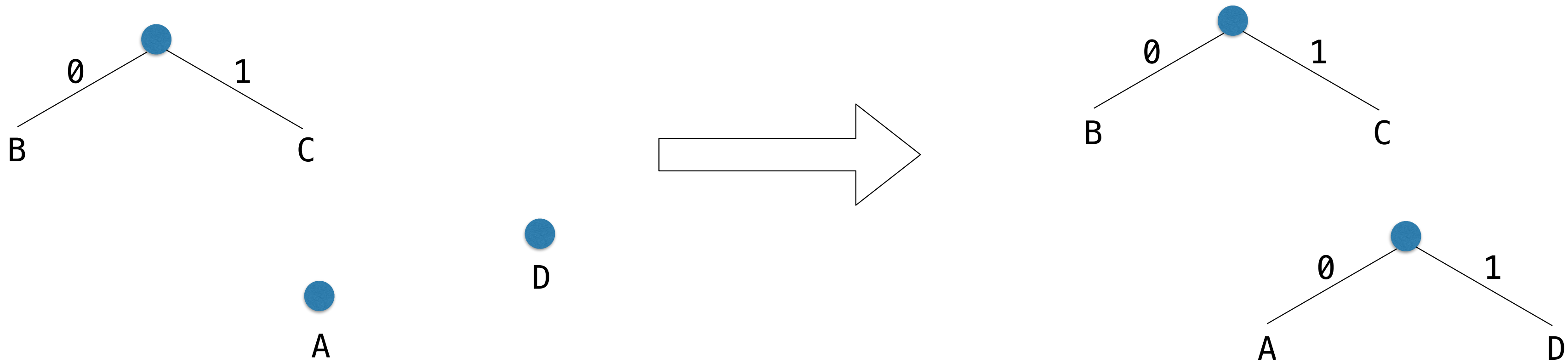

Huffman Encoding

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- And finally…

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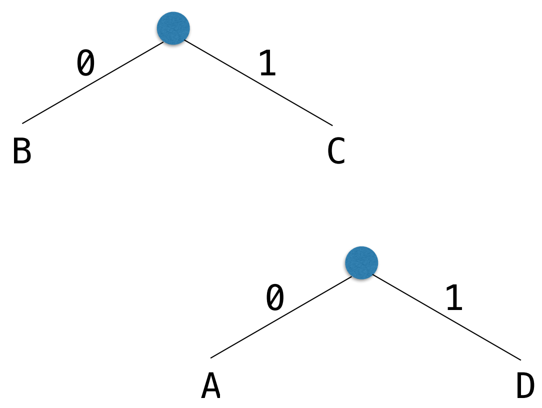

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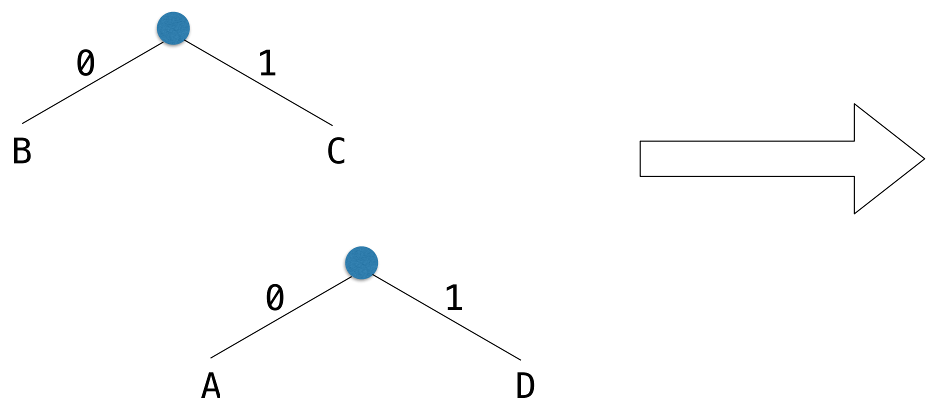

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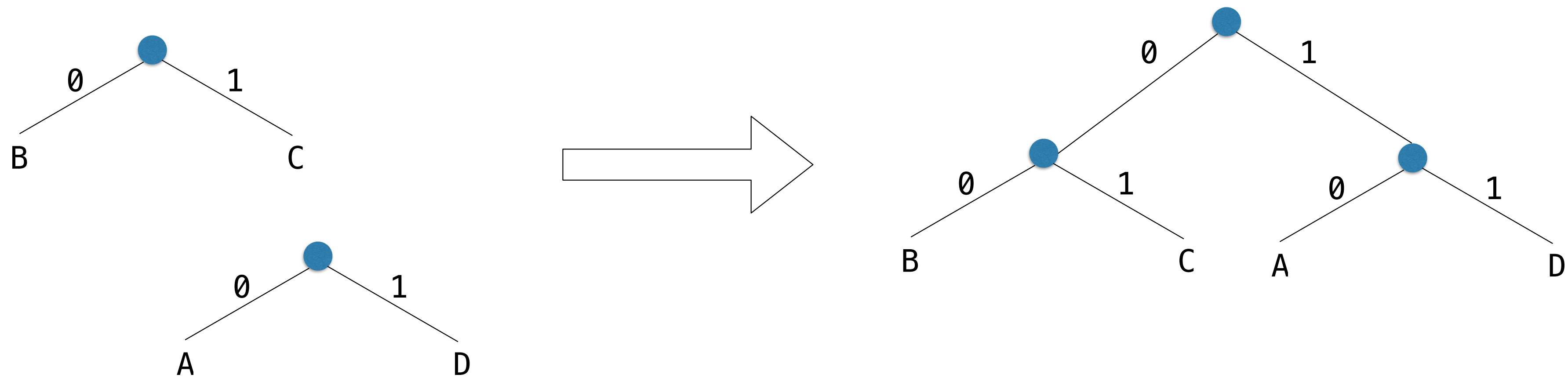

Huffman Encoding

Huffman Encoding

- Another example…

Huffman Encoding

- Another example…
    - AAAAAAAAAABCCD

Huffman Encoding

- Another example…
  - AAAAAAAAAABCCD
  - A appears 10 times

Huffman Encoding

- Another example…
  - AAAAAAAAAABCCD
  - A appears 10 times
  - B appears 1 time

Huffman Encoding

- Another example…
  - AAAAAAAAAABCCD
  - A appears 10 times
  - B appears 1 time
  - C appears 2 times

Huffman Encoding

- Another example…
  - AAAAAAAAAABCCD
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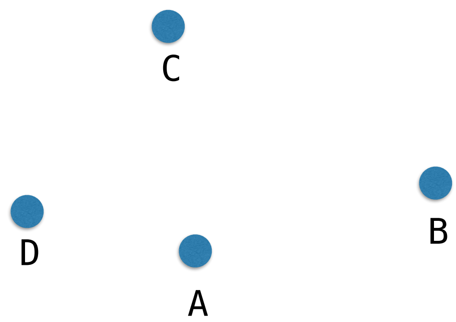

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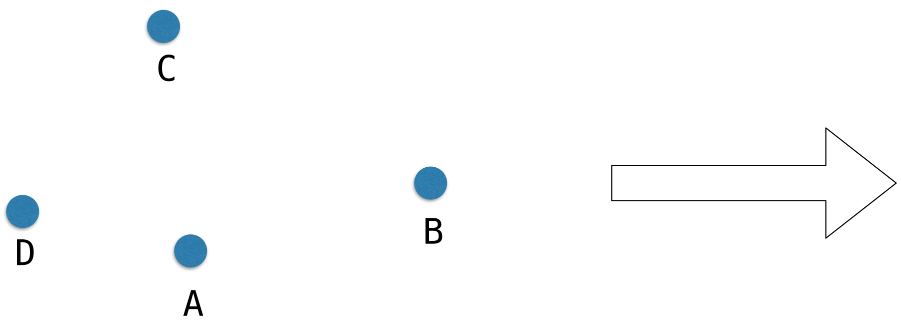

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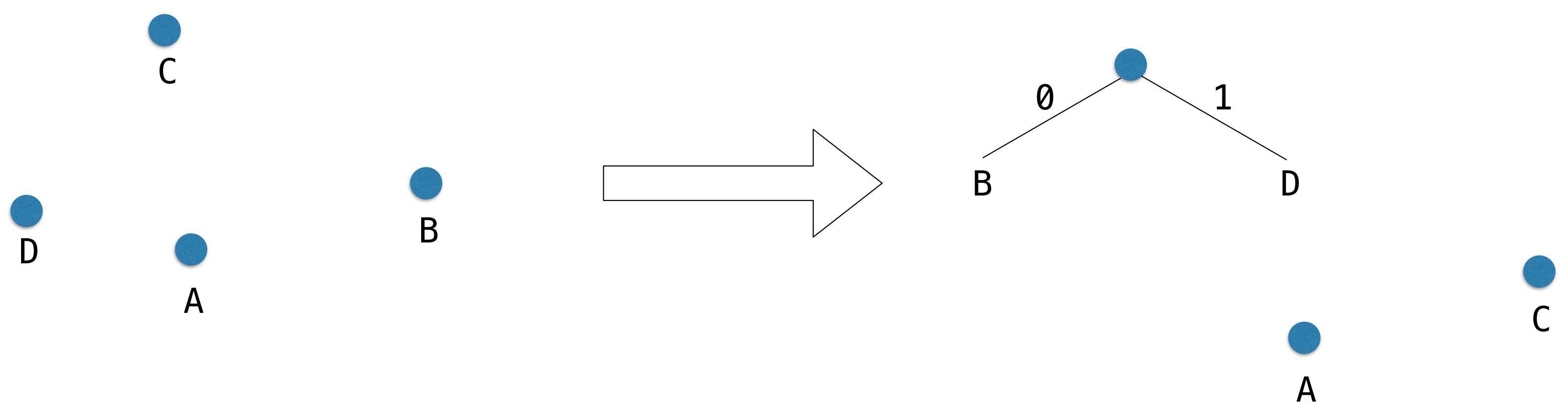

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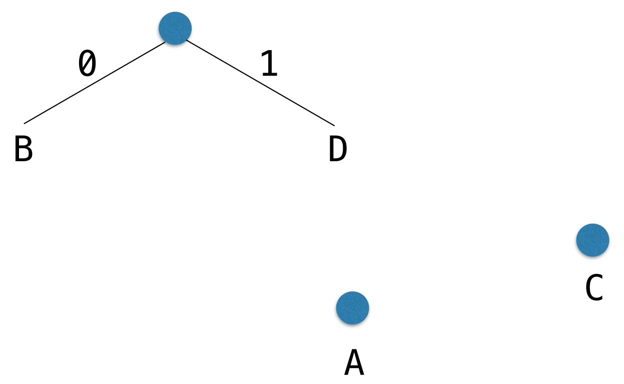

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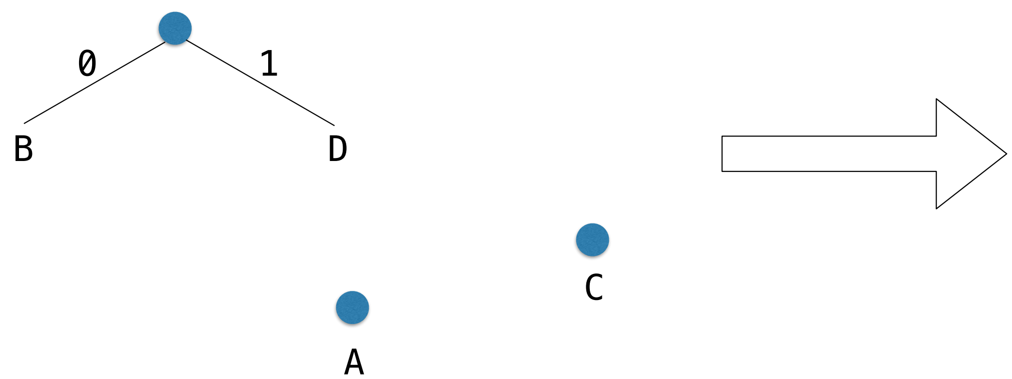

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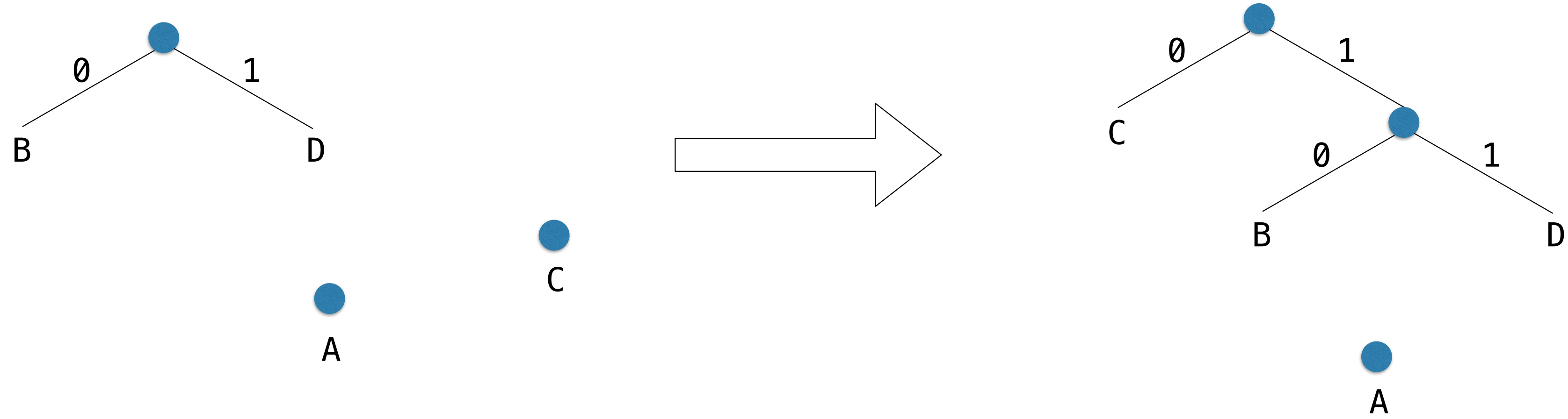

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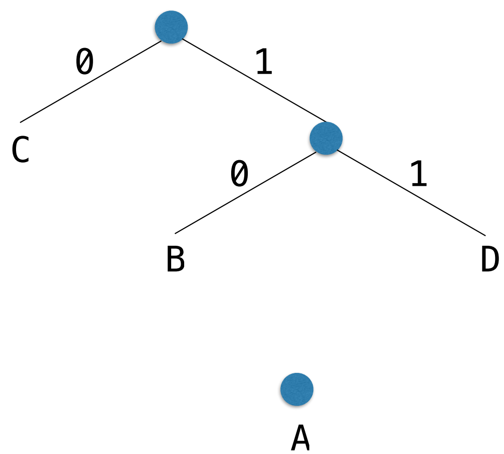

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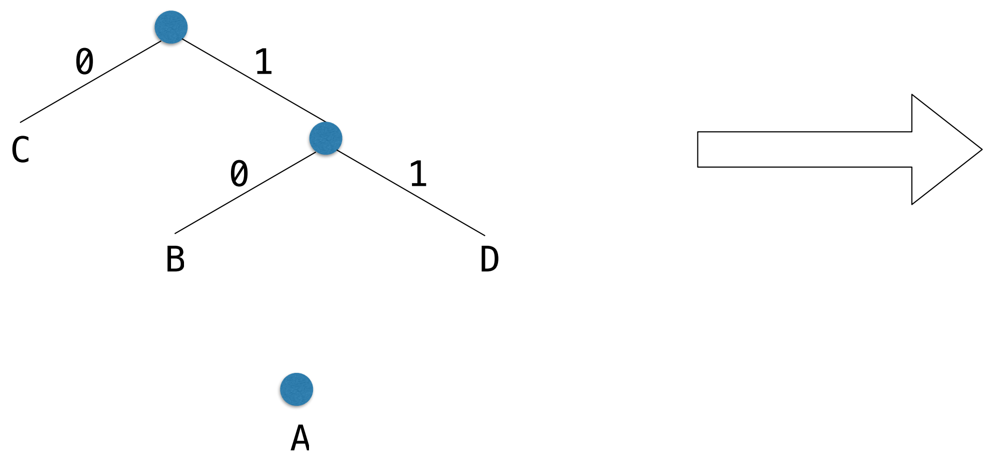

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