

Lecture 09 - Binary Search

Introduction to Data Science and Programming

September 27th, 2023

Find 27746 on this list

76147, 67623, 48945, 57742, 26871, 41422, 45199, 63362,
88012, 9309, 51561, 27822, 93633, 36907, 95025, 32728, 247,
77413, 73272, 73093, 45844, 66414, 35822, 6333, 53442,
21782, 42964, 21185, 26853, 82834, 33775, 57793, 56614,
48533, 34373, 68255, 4840, 9957, 78388, 45958, 12423, 85765,
44128, 67, 95803, 20231, 68859, 13191, 64999, 15897,
93272, 27401, 65458, 25038, 37184, 90380, 16552, 39634,
30550, 69944, 23414, 65548, 70369, 108, 47680, 13269, 22619,
67998, 928, 69559, 81710, 98815, 42231, 13217, 7082,
38306, 73076, 10242, 31335, 88098, 13712, 77346, 75315,
13314, 99294, 14285, 53050, 847, 65002, 44009, 72243, 62808,
15137, 41170, 68656, 85996, 8668, 10046, 75244, 58957,
38403, 96324, 31450, 13983, 27696, 8424, 55339, 60000, 60759,
77896, 69047, 84789, 65840, 30164, 51774, 50952, 74784,
29554, 5456, 89791, 95467, 49488, 11274, 49958, 59392,
52828, 97769, 98688, 93392, 13198, 86081, 56838, 36541,
68294, 76272, 95445, 77036, 1668, 6753, 26218, 3982, 6046,
78928, 50661, 62857, 50104, 41543, 70181, 8242, 53656,
61604, 27746, 30990, 51130, 20319, 80806, 53639, 39073,
63429, 83452, 68105, 6611, 69867, 72995, 84646, 5790, 8621,

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77413, 73272, 73093, 45844, 66414, 35822, 6333, 53442,
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48533, 34373, 68255, 4840, 9957, 78388, 45958, 12423, 85765,
44128, 67, 95803, 20231, 68859, 13191, 64999, 15897,
93272, 27401, 65458, 25038, 37184, 90380, 16552, 39634,
30550, 69944, 23414, 65548, 70369, 108, 47680, 13269, 22619,
67998, 928, 69559, 81710, 98815, 42231, 13217, 7082,
38306, 73076, 10242, 31335, 88098, 13712, 77346, 75315,
13314, 99294, 14285, 53050, 847, 65002, 44009, 72243, 62808,
15137, 41170, 68656, 85996, 8668, 10046, 75244, 58957,
38403, 96324, 31450, 13983, 27696, 8424, 55339, 60000, 60759,
77896, 69047, 84789, 65840, 30164, 51774, 50952, 74784,
29554, 5456, 89791, 95467, 49488, 11274, 49958, 59392,
52828, 97769, 98688, 93392, 13198, 86081, 56838, 36541,
68294, 76272, 95445, 77036, 1668, 6753, 26218, 3982, 6046,
78928, 50661, 62857, 50104, 41543, 70181, 8242, 53656,
61604, 27746, 30990, 51130, 20319, 80806, 53639, 39073,
63429, 83452, 68105, 6611, 69867, 72995, 84646, 5790, 8621,

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| | | | | | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 11274, | 11944, | 11991, | 12423, | 12693, | 12734, | 12879, | 13048, | 13071, | 13191, | 13198, | 13217, | 13269, |
| 13314, | 13351, | 13645, | 13712, | 13723, | 13979, | 13983, | 14064, | 14285, | 15008, | 15137, | 15541, | 15750, |
| 15761, | 15897, | 16383, | 16437, | 16552, | 16696, | 16788, | 16798, | 17280, | 17420, | 17535, | 17610, | 17934, |
| 17981, | 18715, | 18823, | 19542, | 19945, | 20067, | 20146, | 20231, | 20271, | 20319, | 20763, | 21185, | 21471, |
| 21782, | 21880, | 21902, | 21941, | 22089, | 22323, | 22619, | 22840, | 23262, | 23299, | 23414, | 23677, | 23799, |
| 23816, | 24455, | 24512, | 24578, | 24821, | 24954, | 24985, | 25038, | 25511, | 25665, | 25882, | 26016, | 26099, |
| 26218, | 26500, | 26521, | 26652, | 26853, | 26871, | 26876, | 27125, | 27195, | 27198, | 27401, | 27696, | 27746, |
| 27822, | 27977, | 27985, | 28230, | 29510, | 29554, | 30164, | 30176, | 30390, | 30550, | 30682, | 30830, | 30905, |
| 30929, | 30990, | 31335, | 31450, | 31500, | 31805, | 31887, | 32180, | 32358, | 32728, | 32730, | 32779, | 33154, |
| 33775, | 34373, | 34642, | 35480, | 35574, | 35822, | 35911, | 36012, | 36541, | 36768, | 36907, | 37184, | 37223, |
| 37249, | 37280, | 37359, | 37871, | 38297, | 38306, | 38403, | 38593, | 38838, | 39073, | 39160, | 39499, | 39559, |
| 39634, | 40439, | 40651, | 41003, | 41170, | 41199, | 41422, | 41543, | 41625, | 41936, | 42231, | 42964, | 43448, |
| 43498, | 44009, | 44128, | 44343, | 44662, | 45199, | 45220, | 45337, | 45519, | 45844, | 45958, | 46099, | 46204, |
| 46392, | 46509, | 46605, | 47176, | 47680, | 47948, | 48467, | 48533, | 48945, | 49043, | 49202, | 49222, | 49308, |
| 49336, | 49488, | 49958, | 49961, | 50104, | 50204, | 50239, | 50661, | 50882, | 50952, | 51130, | 51345, | 51561, |
| 51774, | 51975, | 52300, | 52581, | 52644, | 52828, | 52943, | 52981, | 53050, | 53442, | 53592, | 53639, | 53656, |

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|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 11274, | 11944, | 11991, | 12423, | 12693, | 12734, | 12879, | 13048, | 13071, | 13191, | 13198, | 13217, | 13269, |
| 13314, | 13351, | 13645, | 13712, | 13723, | 13979, | 13983, | 14064, | 14285, | 15008, | 15137, | 15541, | 15750, |
| 15761, | 15897, | 16383, | 16437, | 16552, | 16696, | 16788, | 16798, | 17280, | 17420, | 17535, | 17610, | 17934, |
| 17981, | 18715, | 18823, | 19542, | 19945, | 20067, | 20146, | 20231, | 20271, | 20319, | 20763, | 21185, | 21471, |
| 21782, | 21880, | 21902, | 21941, | 22089, | 22323, | 22619, | 22840, | 23262, | 23299, | 23414, | 23677, | 23799, |
| 23816, | 24455, | 24512, | 24578, | 24821, | 24954, | 24985, | 25038, | 25511, | 25665, | 25882, | 26016, | 26099, |
| 26218, | 26500, | 26521, | 26652, | 26853, | 26871, | 26876, | 27125, | 27195, | 27198, | 27401, | 27696, | 27746, |
| 27822, | 27977, | 27985, | 28230, | 29510, | 29554, | 30164, | 30176, | 30390, | 30550, | 30682, | 30830, | 30905, |
| 30929, | 30990, | 31335, | 31450, | 31500, | 31805, | 31887, | 32180, | 32358, | 32728, | 32730, | 32779, | 33154, |
| 33775, | 34373, | 34642, | 35480, | 35574, | 35822, | 35911, | 36012, | 36541, | 36768, | 36907, | 37184, | 37223, |
| 37249, | 37280, | 37359, | 37871, | 38297, | 38306, | 38403, | 38593, | 38838, | 39073, | 39160, | 39499, | 39559, |
| 39634, | 40439, | 40651, | 41003, | 41170, | 41199, | 41422, | 41543, | 41625, | 41936, | 42231, | 42964, | 43448, |
| 43498, | 44009, | 44128, | 44343, | 44662, | 45199, | 45220, | 45337, | 45519, | 45844, | 45958, | 46099, | 46204, |
| 46392, | 46509, | 46605, | 47176, | 47680, | 47948, | 48467, | 48533, | 48945, | 49043, | 49202, | 49222, | 49308, |
| 49336, | 49488, | 49958, | 49961, | 50104, | 50204, | 50239, | 50661, | 50882, | 50952, | 51130, | 51345, | 51561, |
| 51774, | 51975, | 52300, | 52581, | 52644, | 52828, | 52943, | 52981, | 53050, | 53442, | 53592, | 53639, | 53656, |

Is “HDKYR” on this list?

| | | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| AGMWB, | ASRNG, | AUQGT, | BGRFD, | BGWLU, | BQFXW, | BRIIW, | CEPRG, | CHHIO, | CLEYN, |
| CQUKB, | DCOHP, | DGSSB, | DIXUW, | DXGPQ, | ECLLM, | ECNQI, | EZGCL, | FFLAI, | FIPFF, |
| FKBJZ, | FNAFQ, | FOSFI, | FYWIR, | FZNCB, | GCHQJ, | GRATU, | GULKY, | HBWYC, | HDKYR, |
| HLPRM, | IAYWV, | ICCWP, | ITBLZ, | IWGEL, | JAJTW, | JFGYQ, | JZNZW, | KHGYL, | KOKFK, |
| KPNYF, | KQFSM, | KXLGG, | LFMXU, | MBTTD, | MOGWL, | NSTRJ, | OFPVA, | OGPXK, | OGSAY, |
| OLABW, | OVQWP, | PESEJ, | PNWEY, | PSNVO, | QAHFT, | QCLLY, | QTNQH, | RKEMD, | RXCKA, |
| RZPYX, | SBFHC, | SFQGM, | SGKRH, | SHIKK, | SIPNK, | SPZRA, | SRZCK, | TIYUW, | TOUNA, |
| UFAFI, | UFAIG, | USIEY, | USNZJ, | VGUCW, | VHRYD, | VTRFF, | WFVLH, | WGNEX, | WHQPD, |
| WKQEY, | WOBZV, | WWJEV, | WZHQK, | WZVWA, | XFGCU, | XOVPD, | XPSWT, | XQH0A, | XTMGG, |
| XVCLH, | YKTOP, | YOMUU, | ZBFGY, | ZNYCZ, | Z0SEH, | ZPOTB, | ZQLND, | ZQORV, | ZYWEM, |

Is “HDKYR” on this list?

| | | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| AGMWB, | ASRNG, | AUQGT, | BGRFD, | BGWLU, | BQFXW, | BRIIW, | CEPRG, | CHHIO, | CLEYN, |
| CQUKB, | DCOHP, | DGSSB, | DIXUW, | DXGPQ, | ECLLM, | ECNQI, | EZGCL, | FFLAI, | FIPFF, |
| FKBJZ, | FNAFQ, | FOSFI, | FYWIR, | FZNCB, | GCHQJ, | GRATU, | GULKY, | HBWYC, | HDKYR, |
| HLPRM, | IAYWV, | ICCWP, | ITBLZ, | IWGEL, | JAJTW, | JFGYQ, | JZNZW, | KHGYL, | KOKFK, |
| KPNYF, | KQFSM, | KXLGG, | LFMXU, | MBTTD, | MOGWL, | NSTRJ, | OFPVA, | OGPXK, | OGSAY, |
| OLABW, | OVQWP, | PESEJ, | PNWEY, | PSNVO, | QAHFT, | QCLLY, | QTNQH, | RKEMD, | RXCKA, |
| RZPYX, | SBFHC, | SFQGM, | SGKRR, | SHIKK, | SIPNK, | SPZRA, | SRZCK, | TIYUW, | TOUNA, |
| UFAFI, | UFAIG, | USIEY, | USNZJ, | VGUCW, | VHRYD, | VTRFF, | WFVLH, | WGNEX, | WHQPD, |
| WKQEY, | WOBZV, | WWJEV, | WZHQK, | WZVWA, | XFGCU, | XOVDP, | XPSWT, | XQH0A, | XTMGG, |
| XVCLH, | YKTOP, | YOMUU, | ZBFGY, | ZNYCZ, | Z0SEH, | ZPOTB, | ZQLND, | ZQORV, | ZYWEM, |

Is “NAOKK” on this list?

| | | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| JFGYQ, | PESEJ, | ZQORV, | UFAIG, | FYWIR, | KXLGG, | OGPXK, | FZNCB, | CQUKB, | JZNZW, |
| ASRNG, | QCLLY, | WGNEX, | WHQPD, | TOUNA, | IAYWV, | HBWYC, | MBTTD, | MOGWL, | FOSFI, |
| ZQLND, | FIPFF, | BQFXW, | BGRFD, | YOMUU, | ECLLM, | SRZCK, | IWGEL, | KHGYL, | WOBZV, |
| ZYWEM, | FKBJZ, | GULKY, | ZOSEH, | ZPOTB, | PNWEY, | CEPRG, | DXGPQ, | KPNYF, | SGKRR, |
| ITBLZ, | ZBFGY, | WWJEV, | SPZRA, | VHRYD, | DCOHP, | SFQGM, | XVCLH, | AUQGT, | OLABW, |
| XOVPD, | DIXUW, | XFGCU, | WKQEY, | WZVWA, | TIYUW, | VGUCW, | WFVLH, | UFAFI, | WZHQK, |
| ZNYCZ, | EZGCL, | SIPNK, | OGSAY, | NSTRJ, | BRIIW, | SHIKK, | HDKYR, | XQH0A, | HLPRM, |
| LFMXU, | ECNQI, | VTRFF, | AGMWB, | KQFSM, | GRATU, | CLEYN, | BGWLU, | RZPYX, | PSNVO, |
| XTMGG, | QTNQH, | CHHIO, | DGSSB, | KOKFK, | XPSWT, | JAJTW, | YKTOP, | FFLAI, | RKEMD, |

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JFGYQ, PESEJ, ZQORV, UFAIG, FYWIR, KXLGG, OGPXK, FZNCB, CQUKB, JZNZW,
ASRNG, QCLLY, WGNEX, WHQPD, TOUNA, IAYWV, HBWYC, MBTTD, MOGWL, FOSFI,
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ITBLZ, ZBFGY, WWJEV, SPZRA, VHRYD, DCOHP, SFQGM, XVCLH, AUQGT, OLABW,
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LFMXU, ECNQI, VTRFF, AGMWB, KQFSM, GRATU, CLEYN, BGWLU, RZPYX, PSNVO,
XTMGG, QTNQH, CHHIO, DGSSB, KOKFK, XPSWT, JAJTW, YKTOP, FFLAI, RKEMD,

No - but what an annoying task!

The Guessing Game

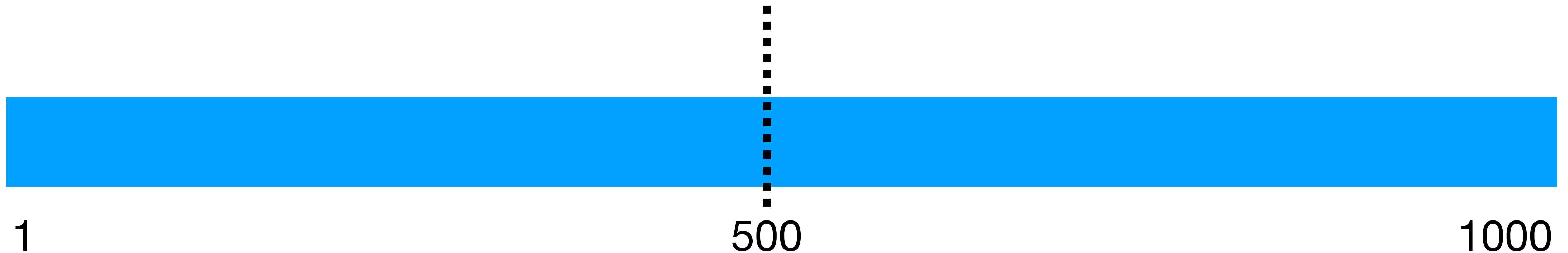
1 volunteer

The Guessing Game

- * think of a number from 1 to 1000
- * write it on the blackboard
- * we will ask you questions to guess your number
- * how many questions do you think we will need?

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



Q1: Is it 500; higher; or lower?

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



1

500

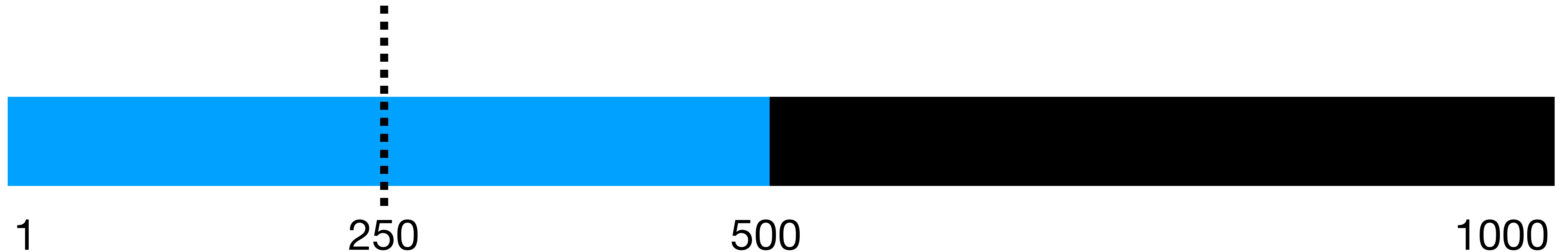
1000

It's < 500 , so our search space is cut in half; find a new “midpoint” to ask about

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



Is it 250; higher; or lower?

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



1

250

500

1000

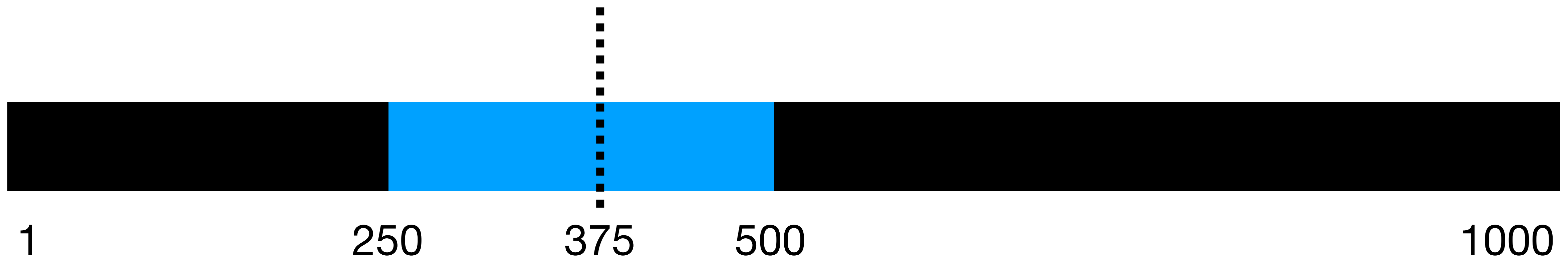
It's >250 , so our search space is cut in half, find a new midpoint again!

My number: 277

Formula for midpoint?

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



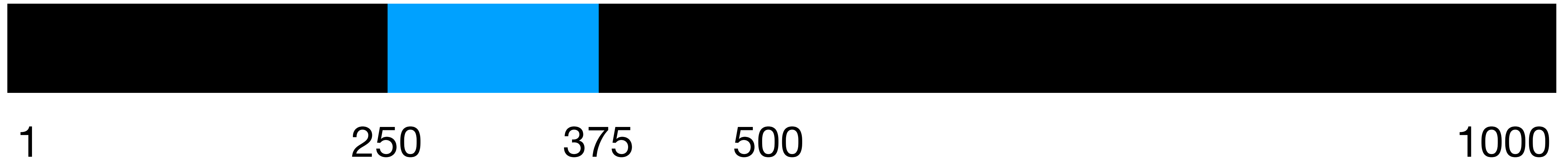
It's >250, so our search space is cut in half, find a new midpoint again!

My number: 277

Formula for midpoint? $(\text{higher_limit} + \text{lower_limit}) / 2$

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



It's lower than 375

My number: 277

Strategy: Cut the search space in half

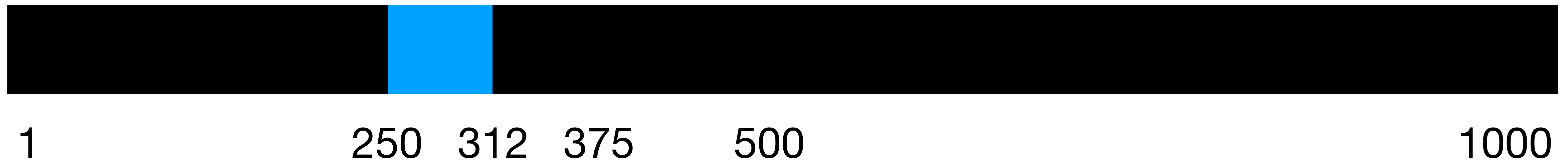
...with each question; this strategy is called “binary search algorithm”



My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



It's lower than 312

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”

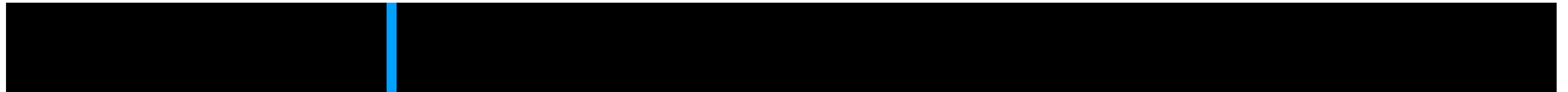


It's lower than 281

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”



1

etc. - until we narrow down
on exactly the number 277!

1000

My number: 277

Strategy: Cut the search space in half

...with each question; this strategy is called “binary search algorithm”

```
[(base) anvy@mac622265 lecture09 % python guessing_game.py
Think of a number between 1 and 1000!
Is the number 500; lower; or higher? (Y/L/H) l
Is the number 250; lower; or higher? (Y/L/H) h
Is the number 375; lower; or higher? (Y/L/H) l
Is the number 312; lower; or higher? (Y/L/H) l
Is the number 281; lower; or higher? (Y/L/H) l
Is the number 265; lower; or higher? (Y/L/H) h
Is the number 273; lower; or higher? (Y/L/H) h
Is the number 277; lower; or higher? (Y/L/H) y
Game over. I found the number in 8 questions!
(base) anvy@mac622265 lecture09 %
```

My number: 277