Storage & Indexing in Modern Databases

ECS 165A – Winter 2026

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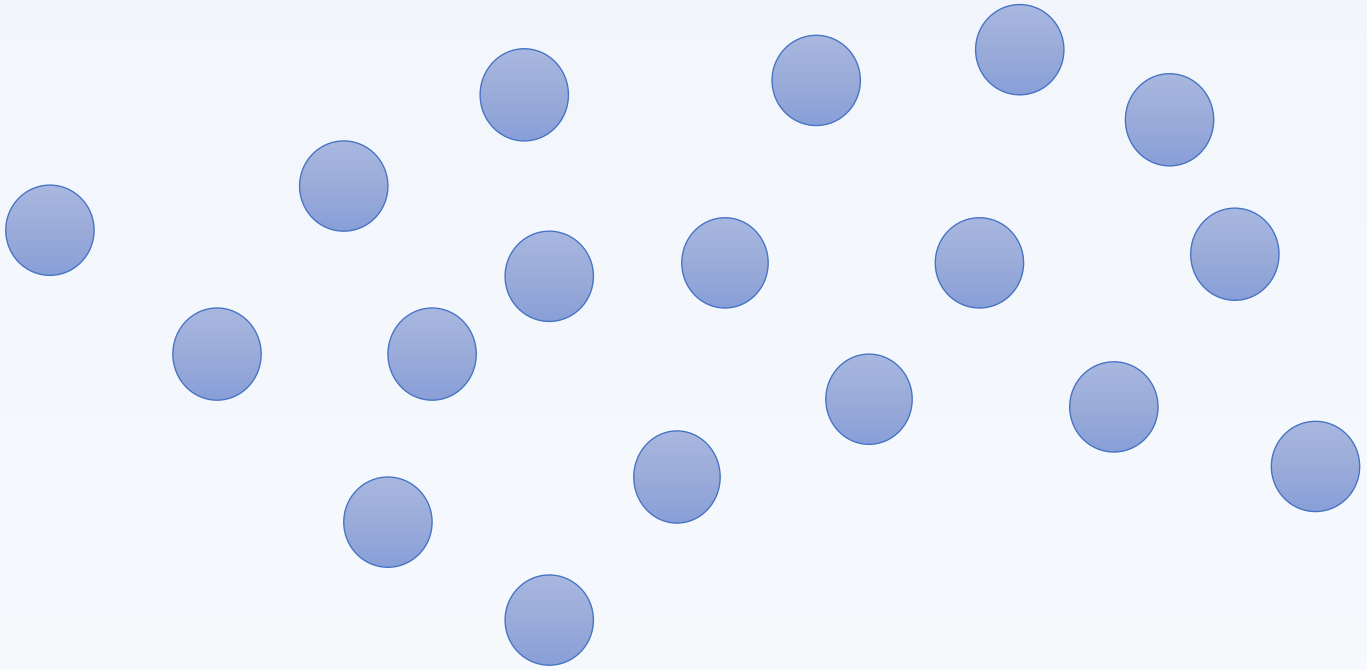
Exploratory Systems Lab
Department of Computer Science

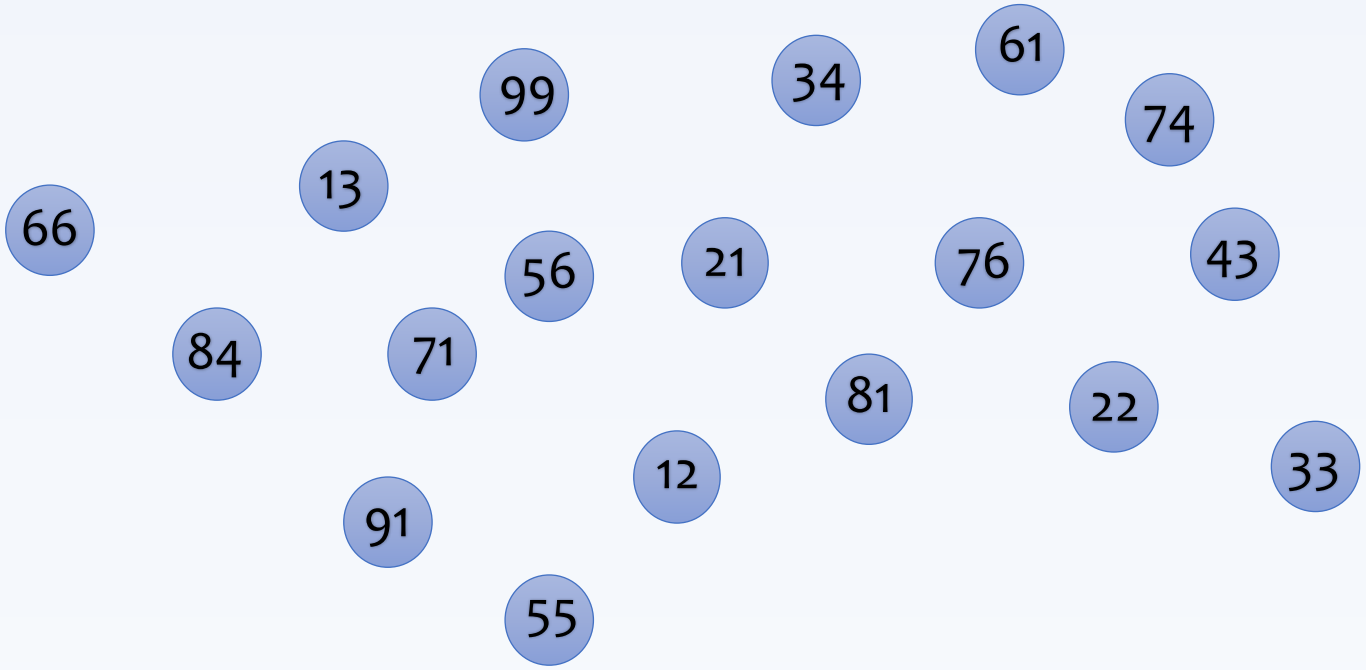
UCDAVIS
UNIVERSITY OF CALIFORNIA

Apache ResilientDB Incubating

ExpoLab
Creativity Unfolded

How to quickly search for the desired information?

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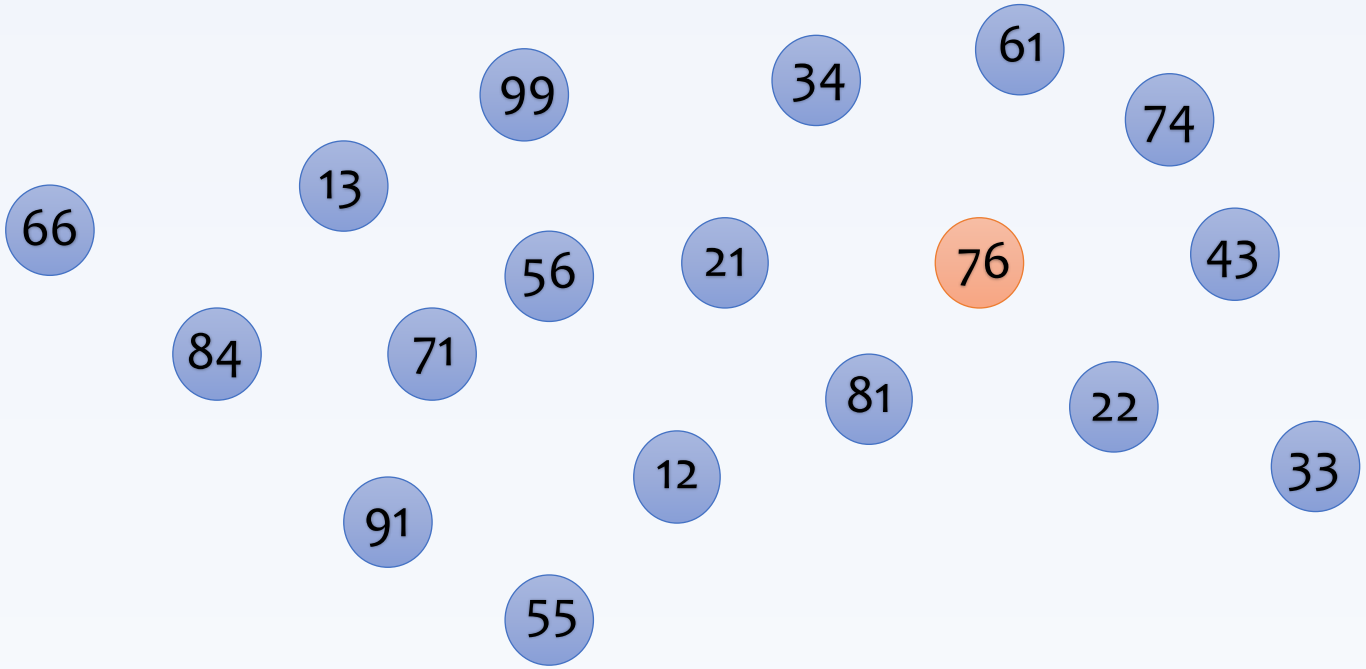
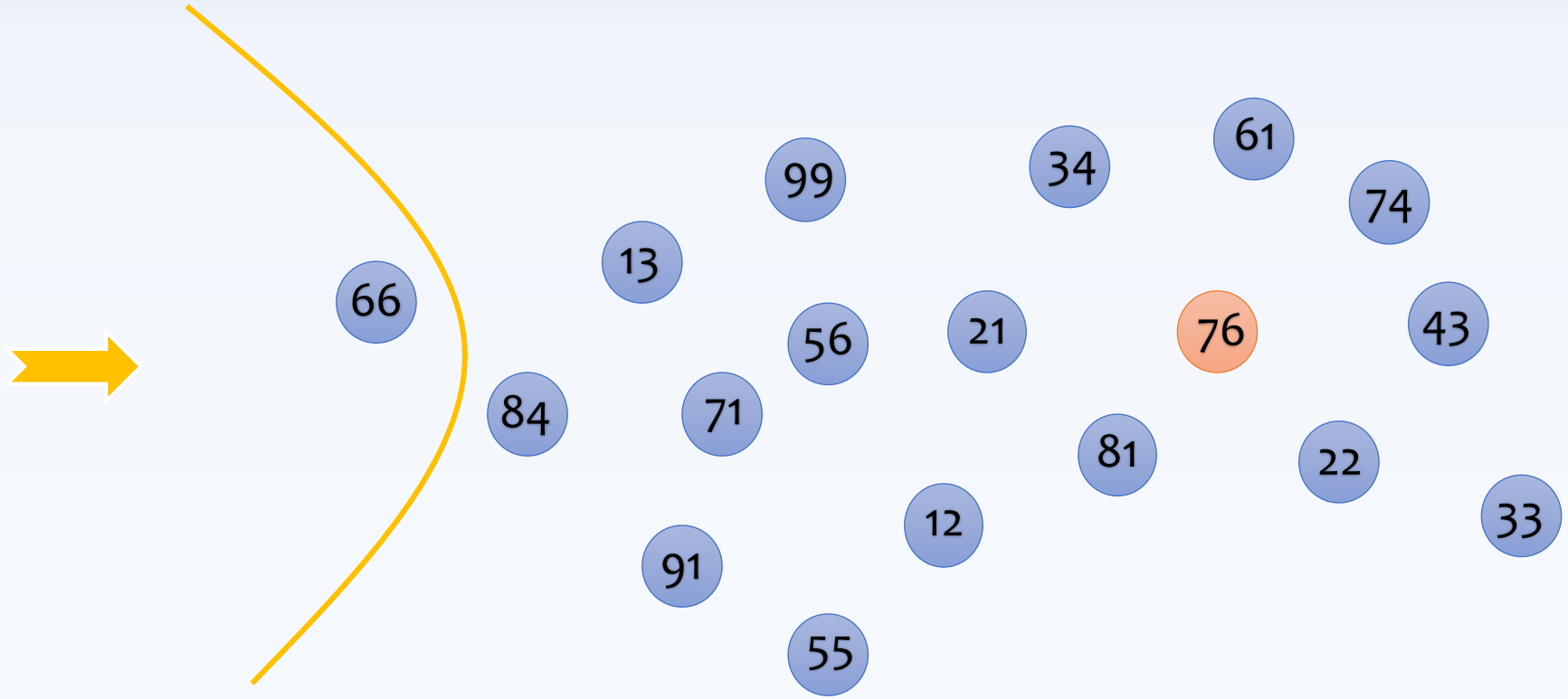
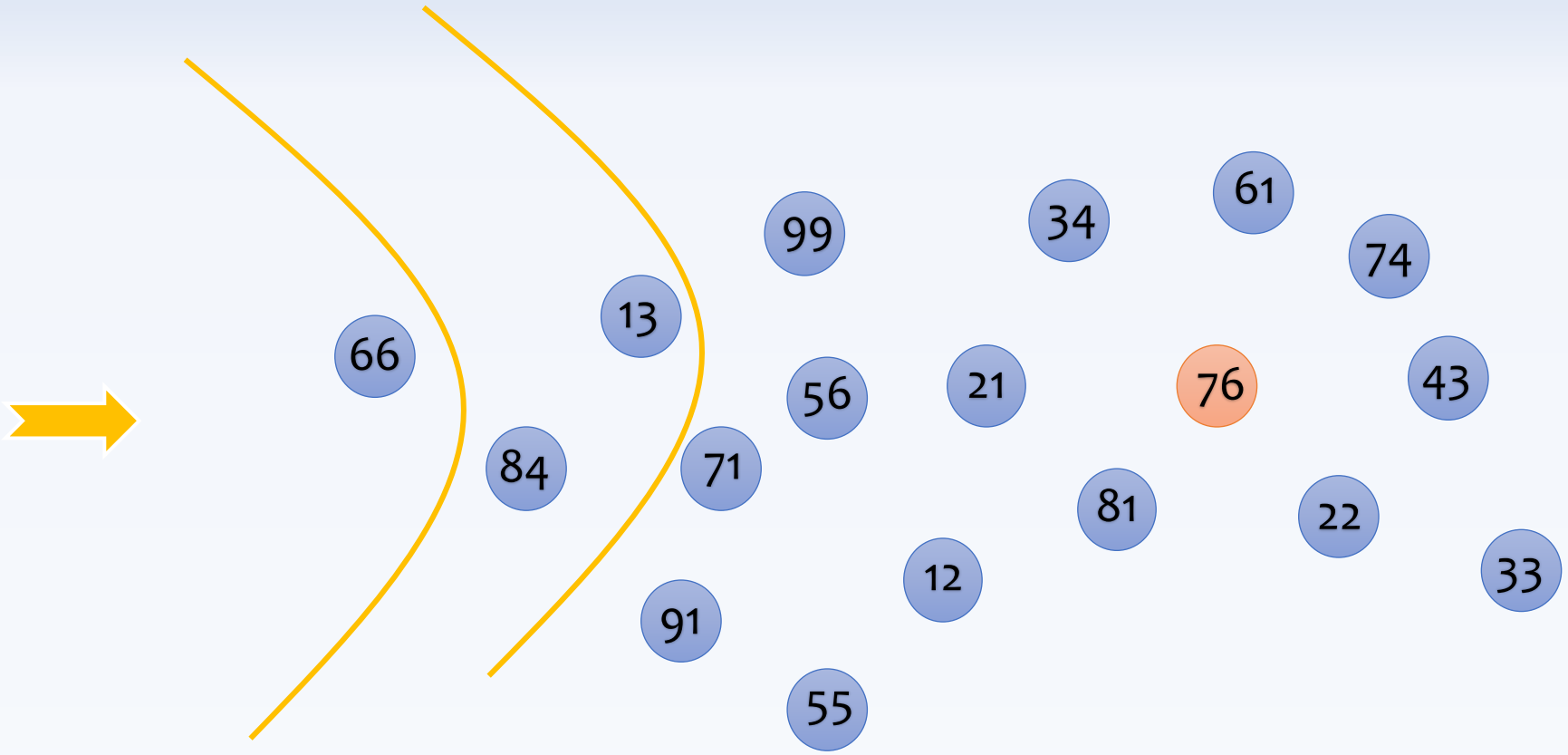
Searching for 76



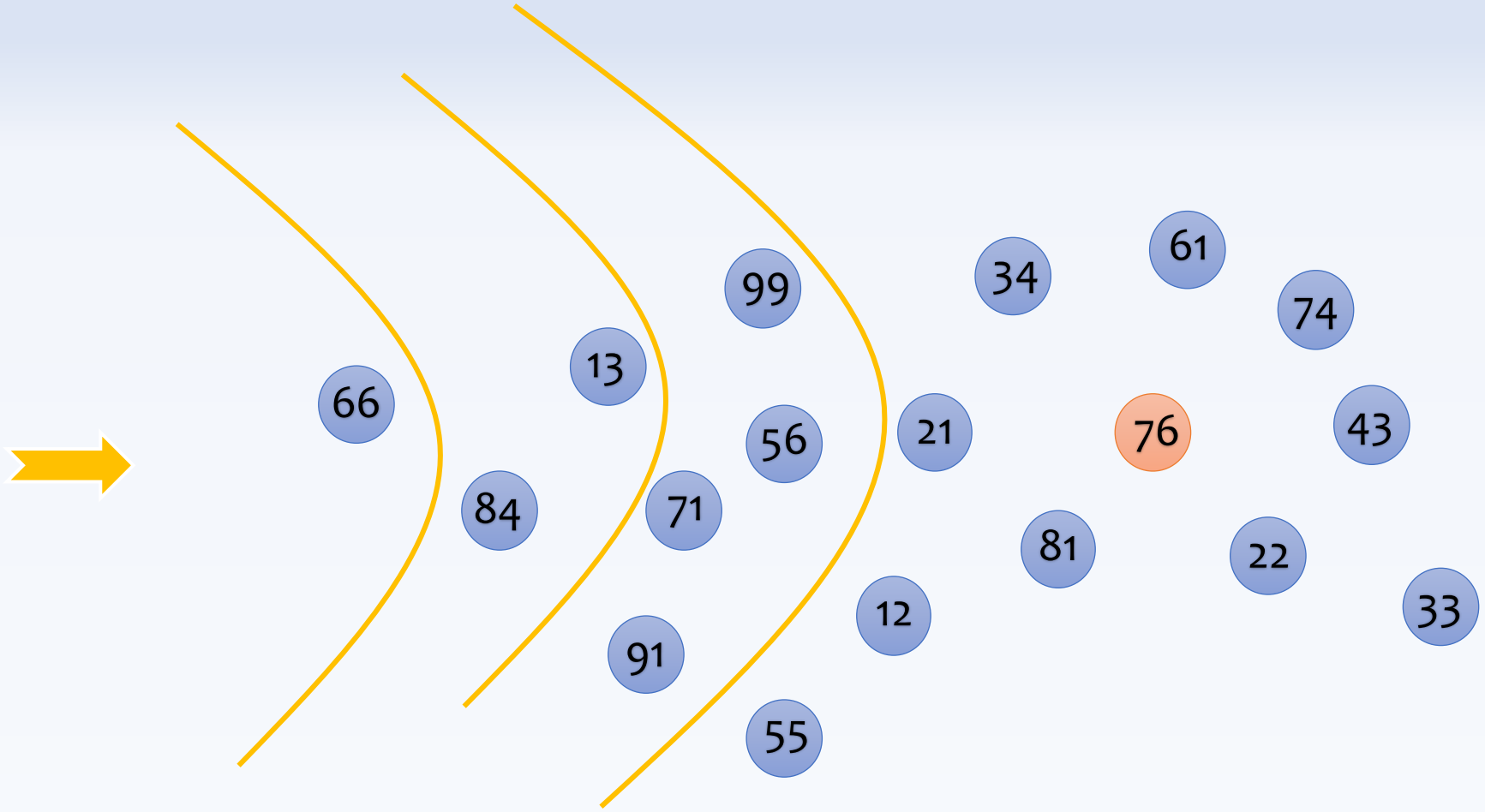
Searching for 76



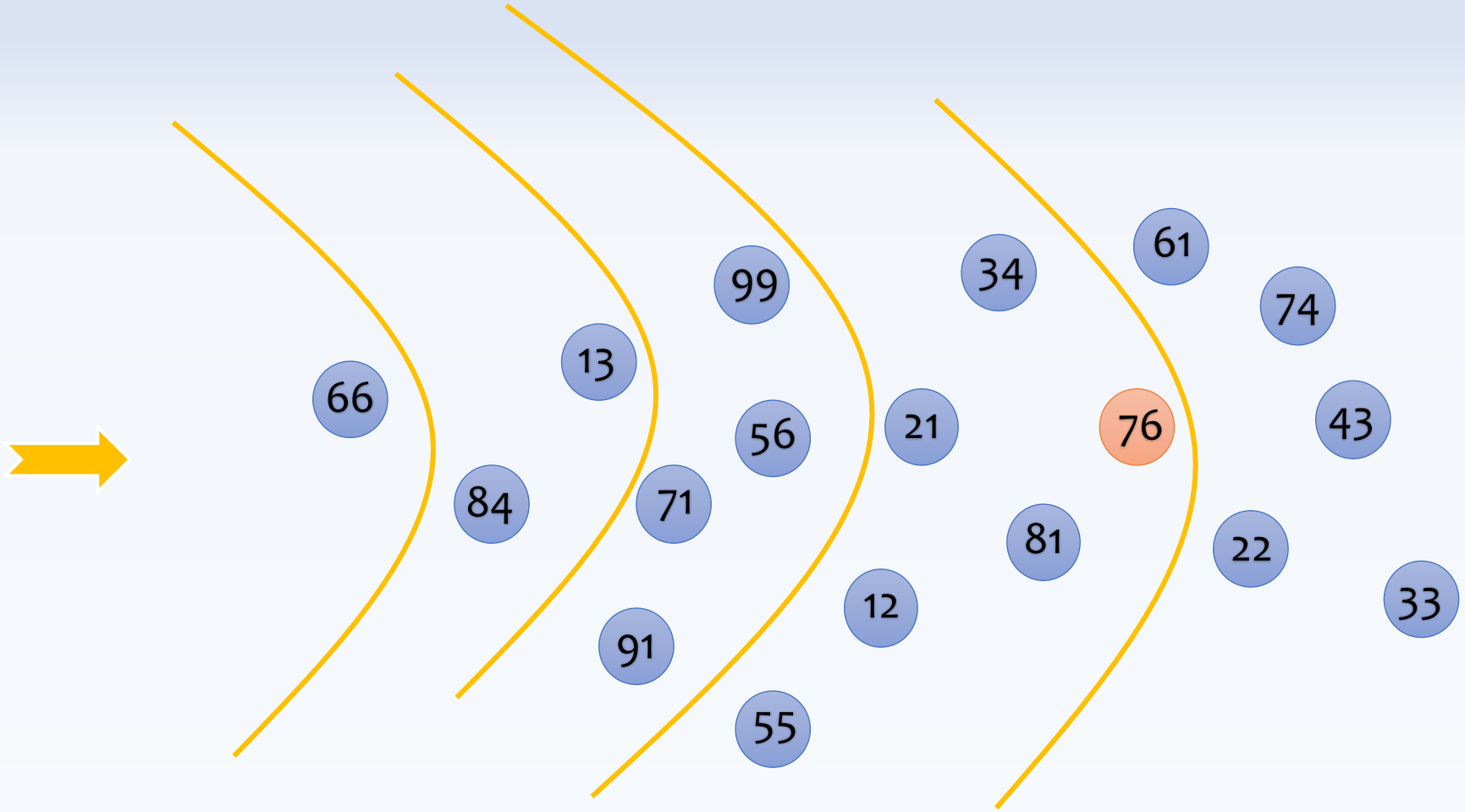
Searching for 76



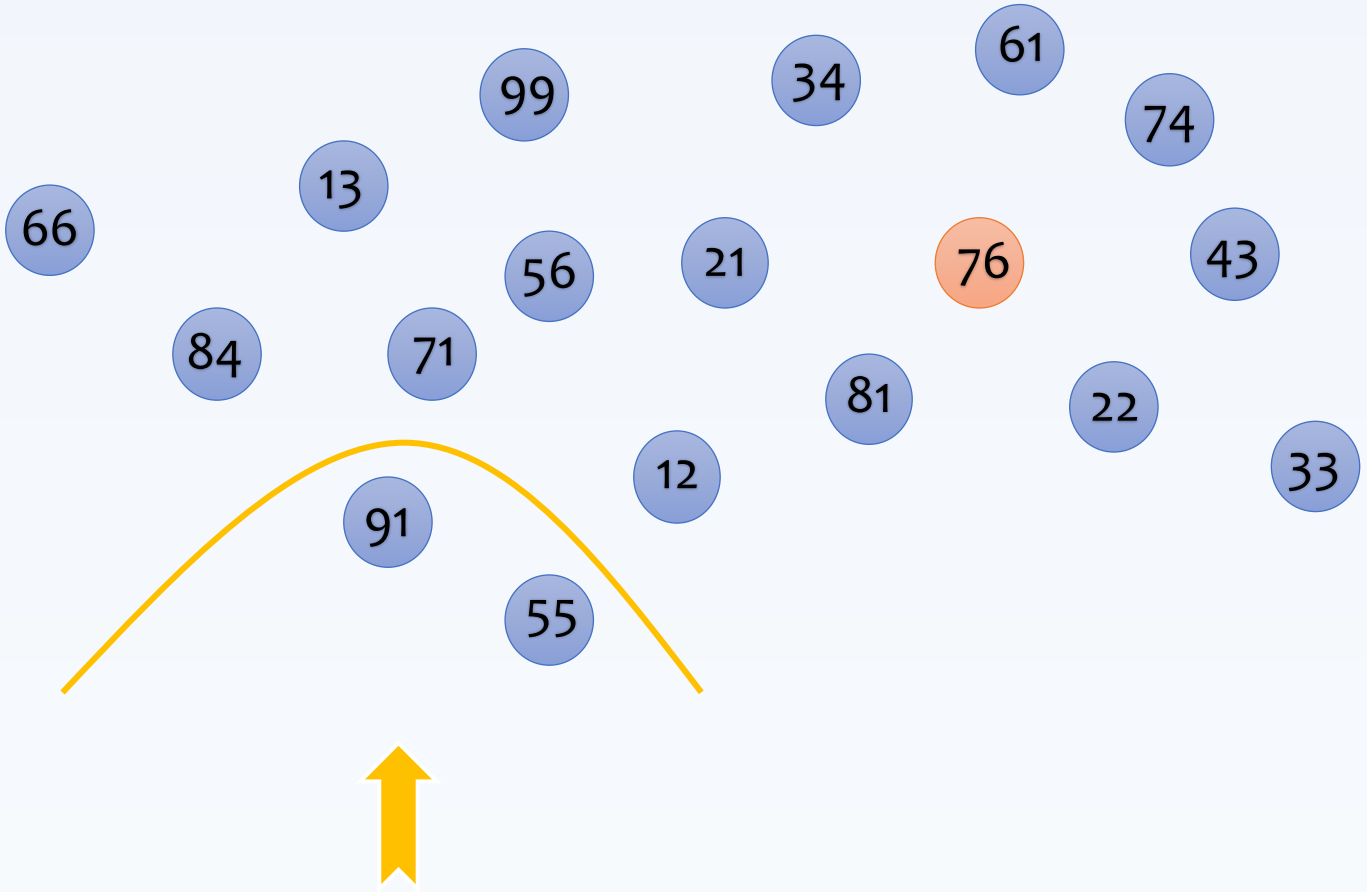
Searching for 76



Searching for 76



Searching for 76



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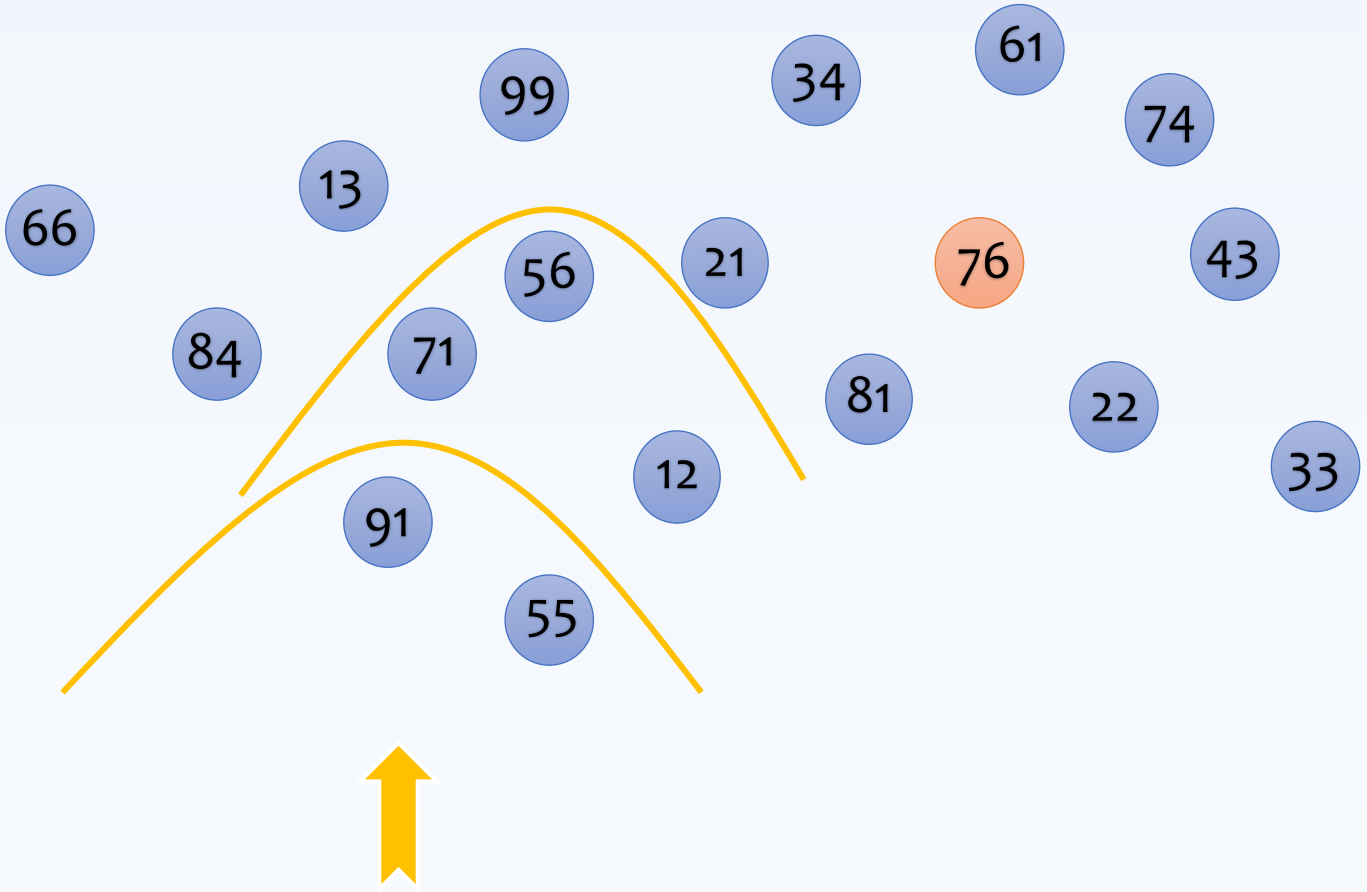
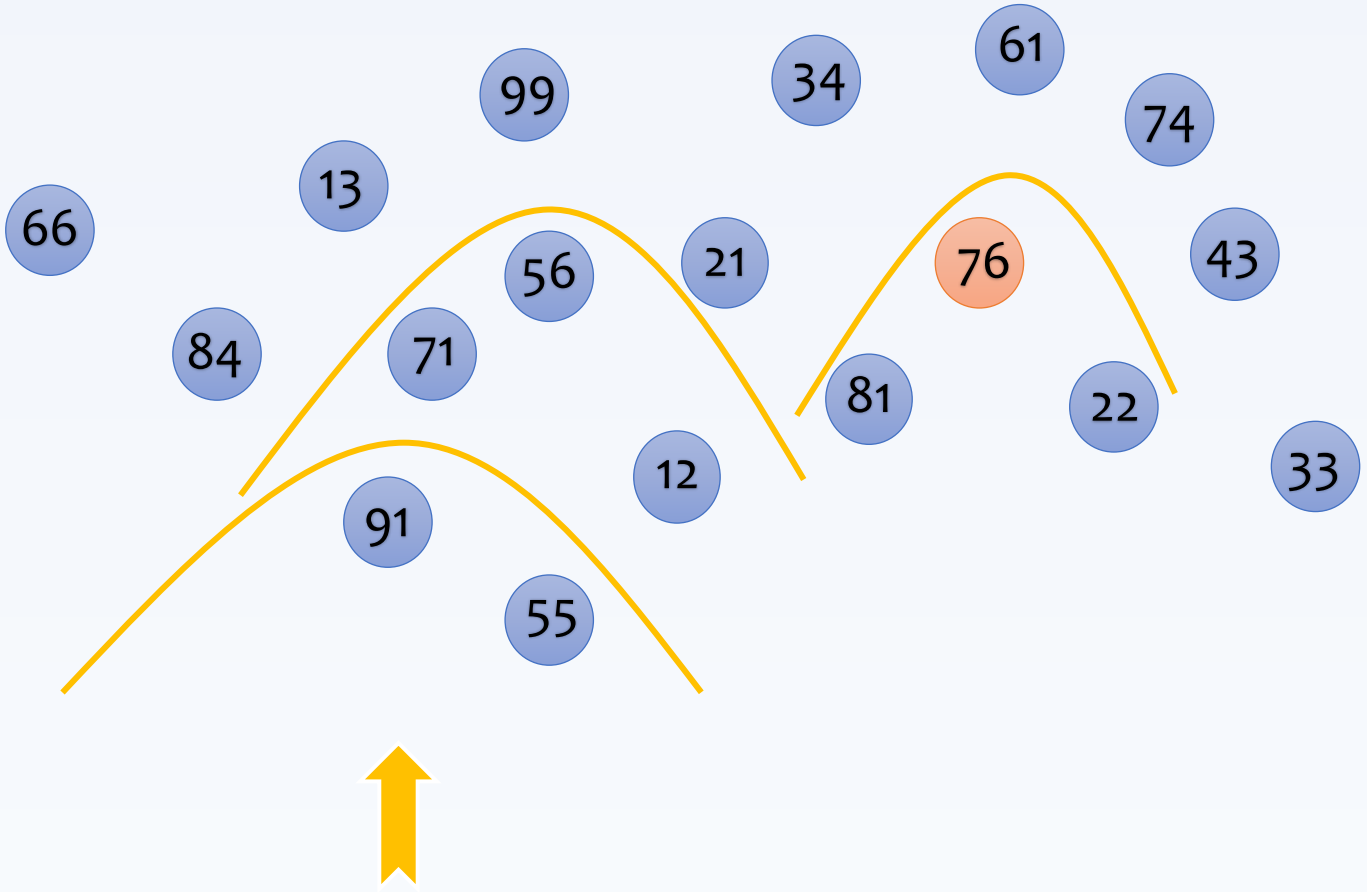


Searching for 76



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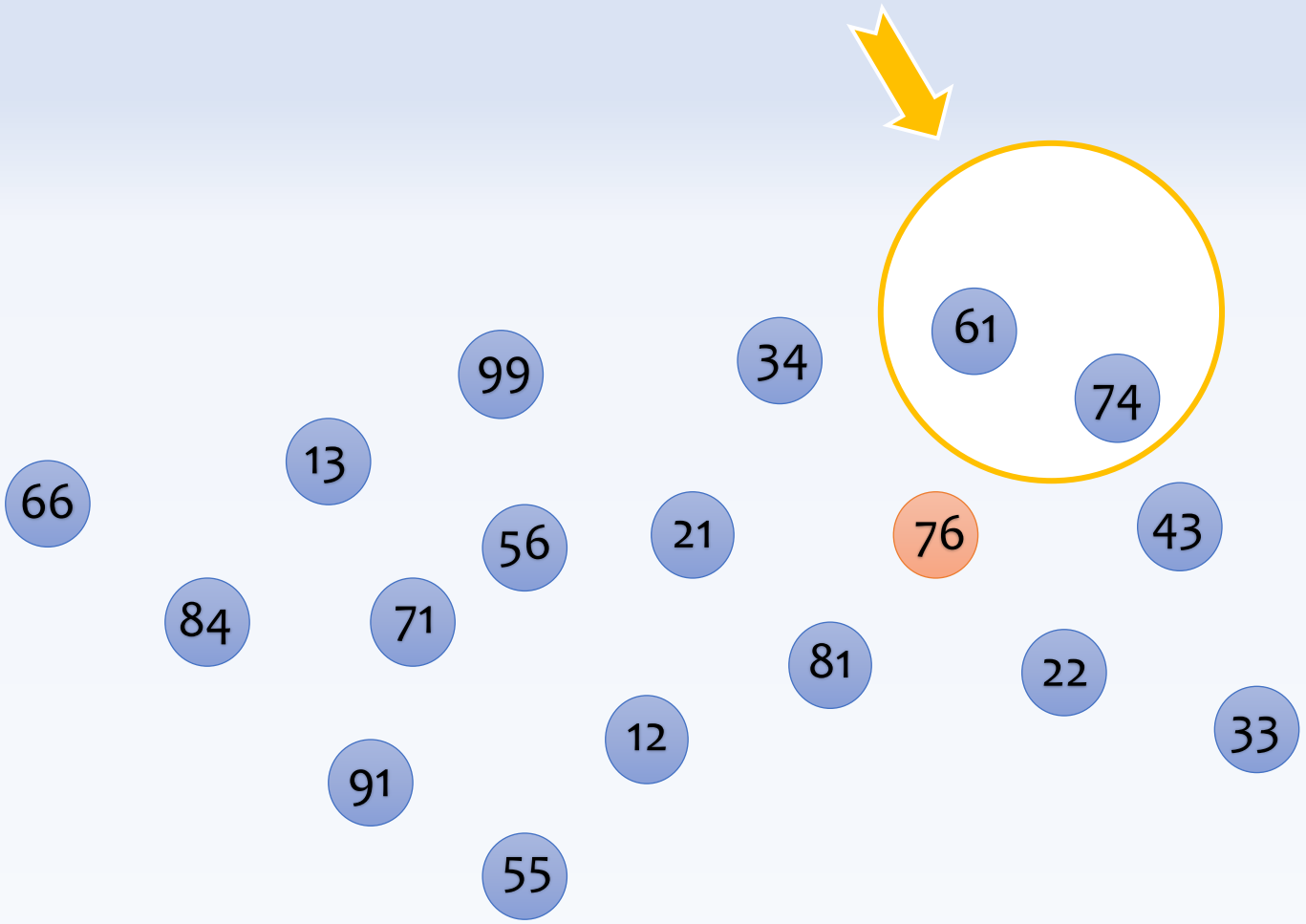

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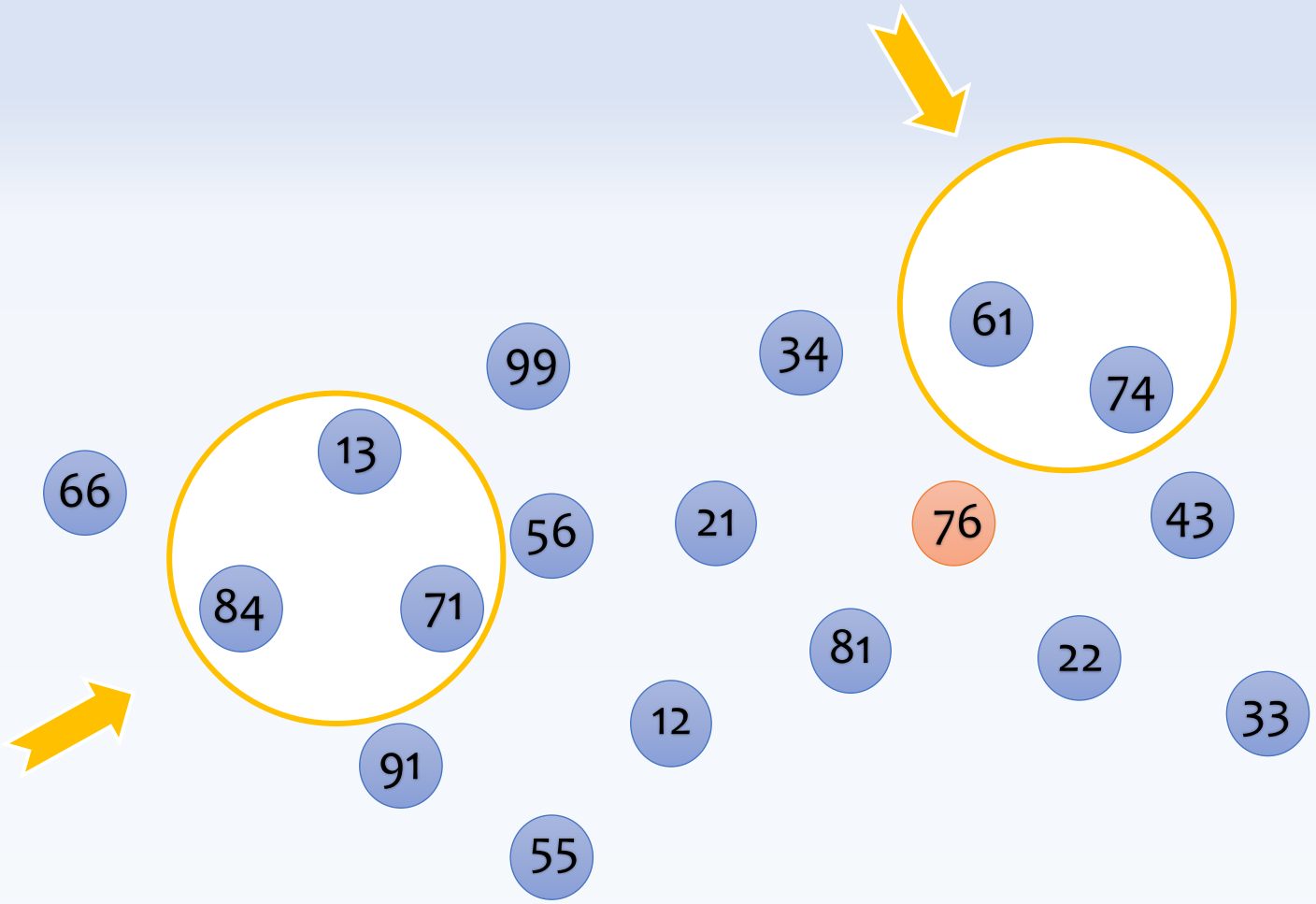
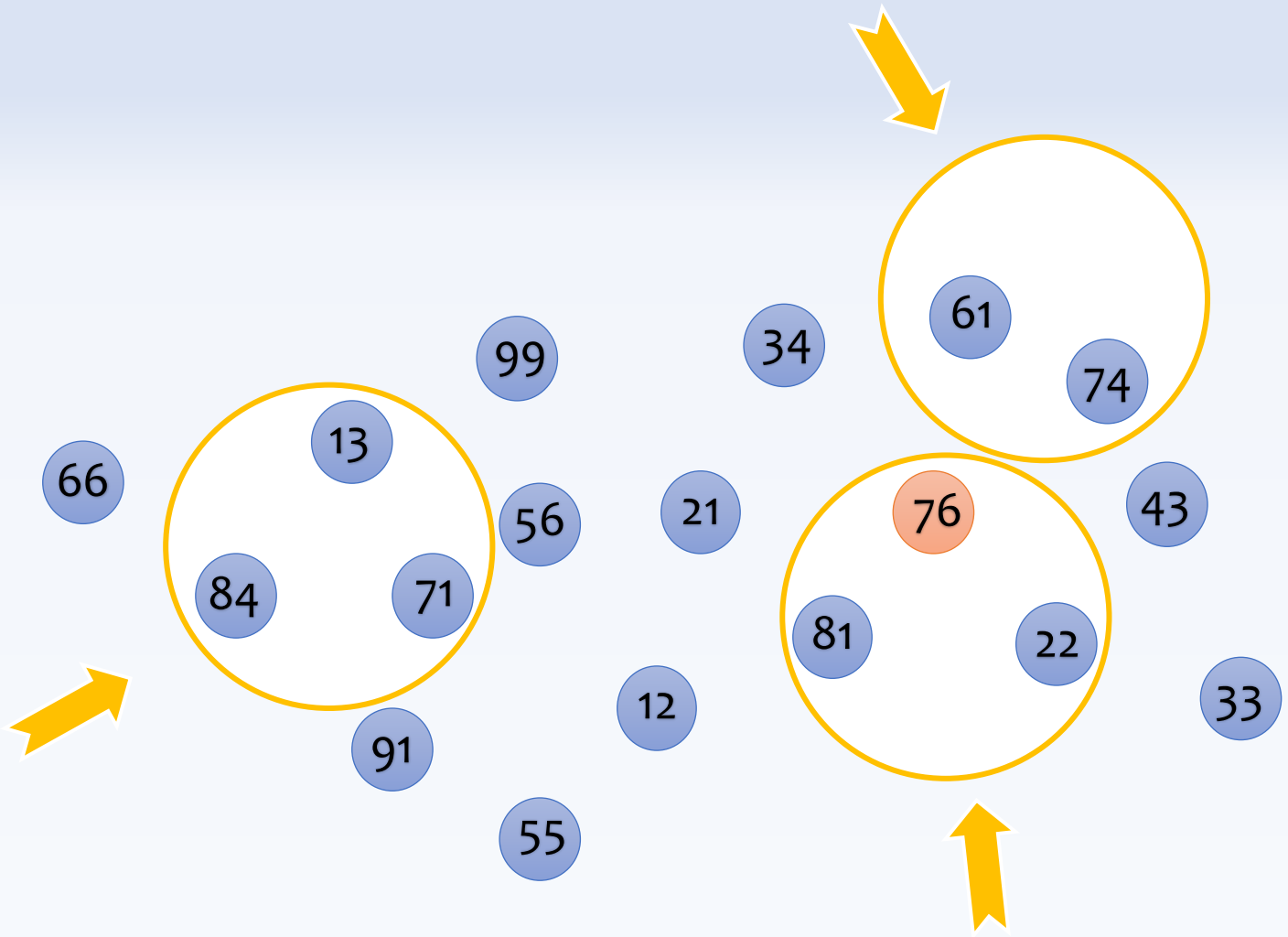


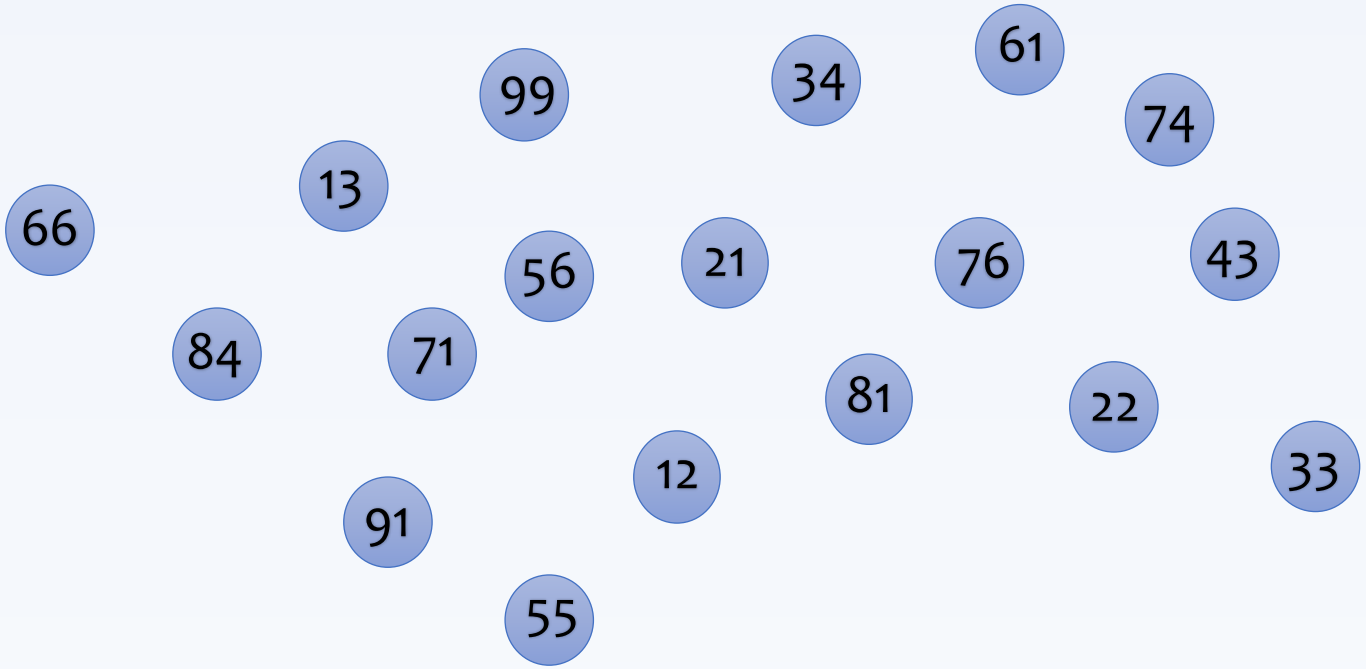
Searching for 76



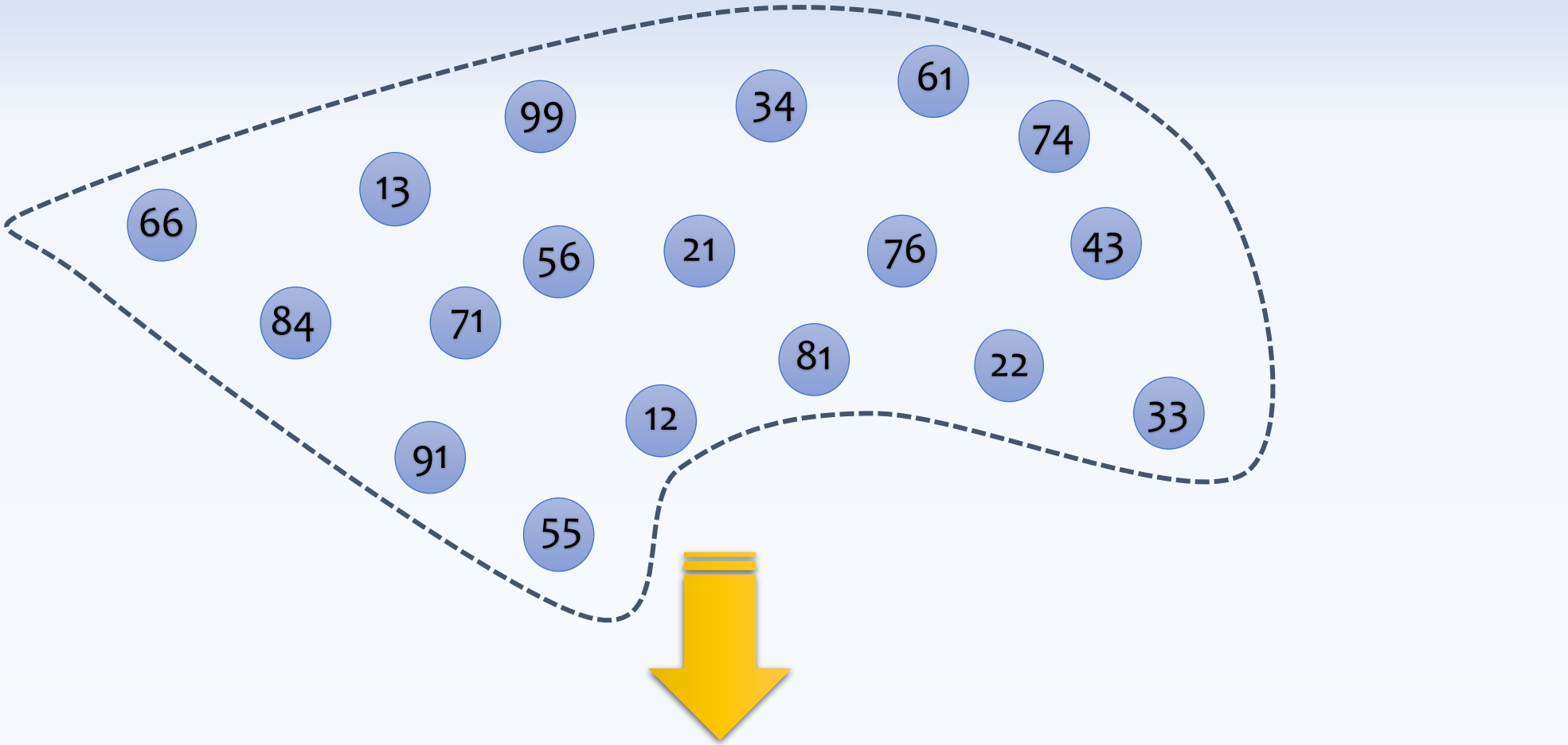
Searching for 44?

(what-if the value does not exist)

(could we have an early termination?)



Could we impose an order to improve the search?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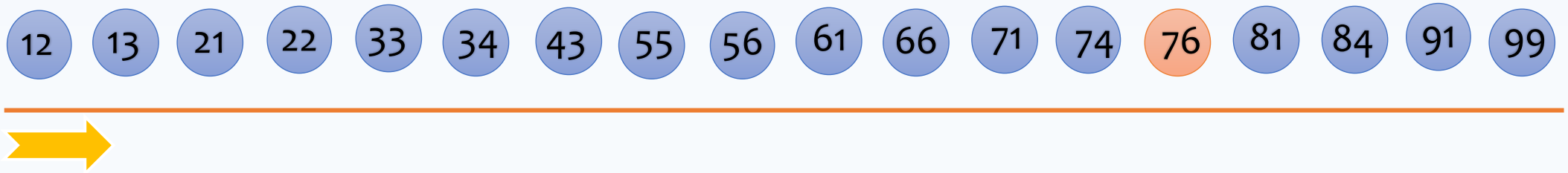
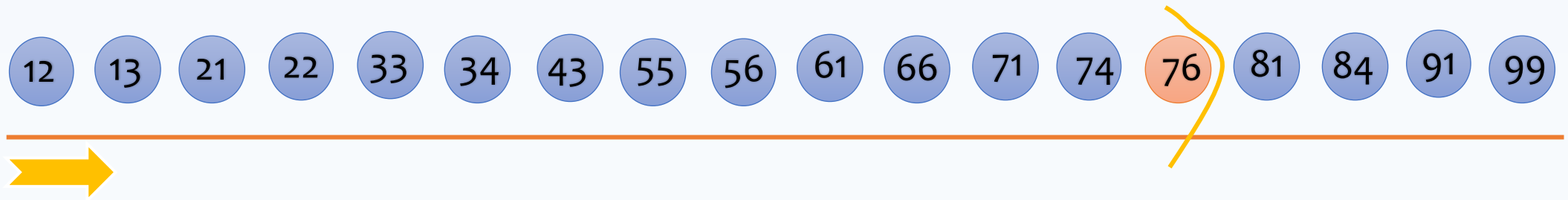
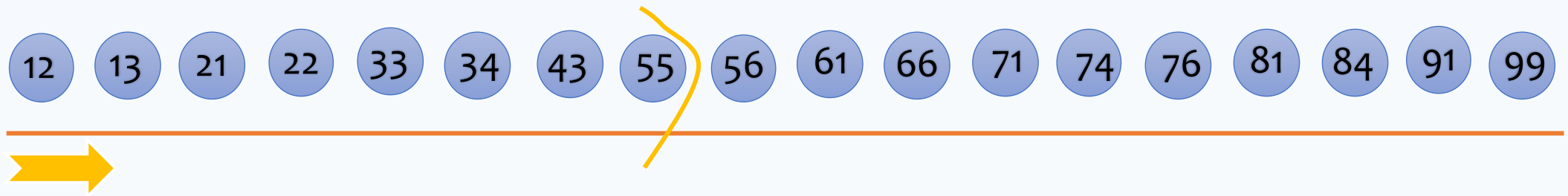
Searching for 76



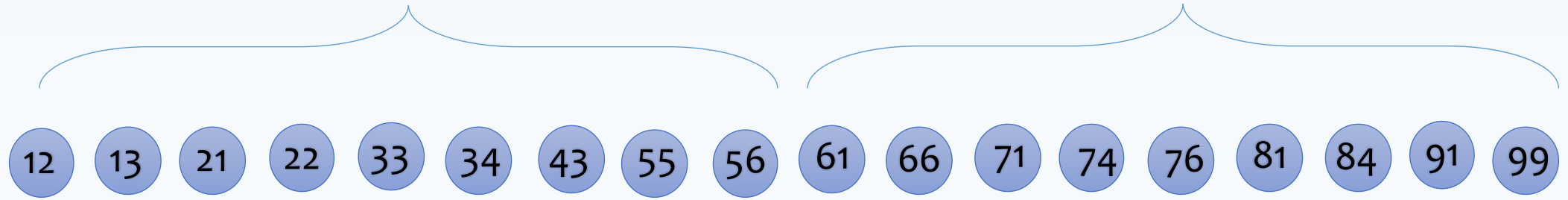
Searching for 76



Searching for 44?
(could we have an early termination?)



Could we impose a structure to further improve the search?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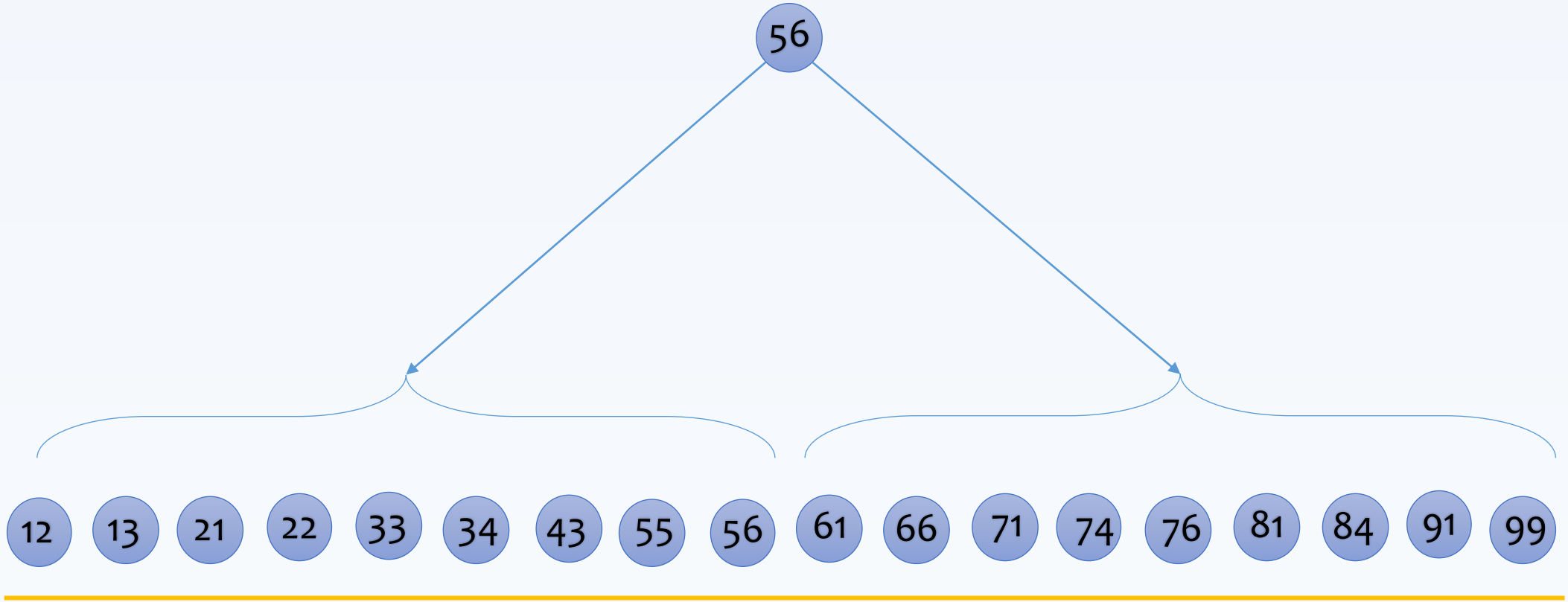
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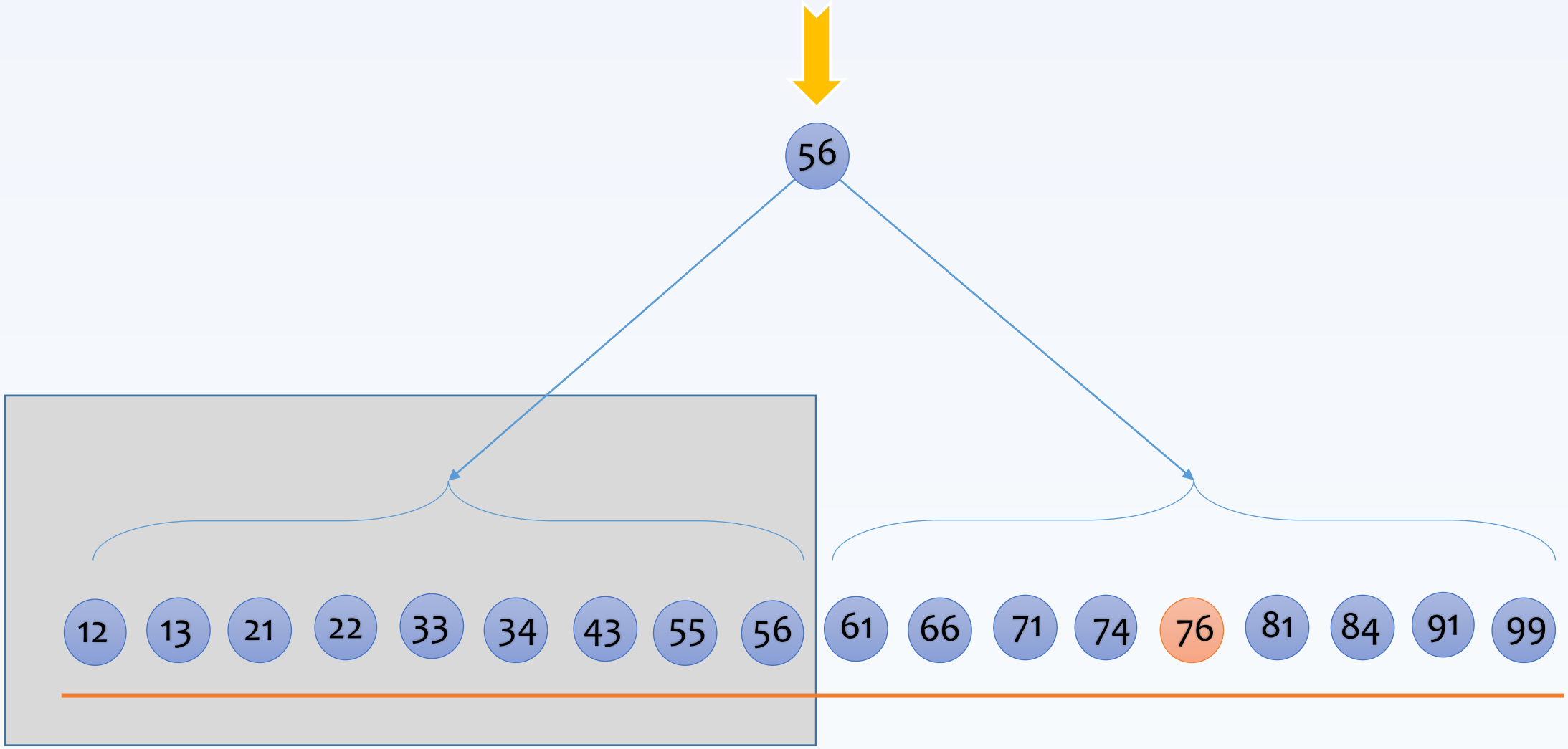
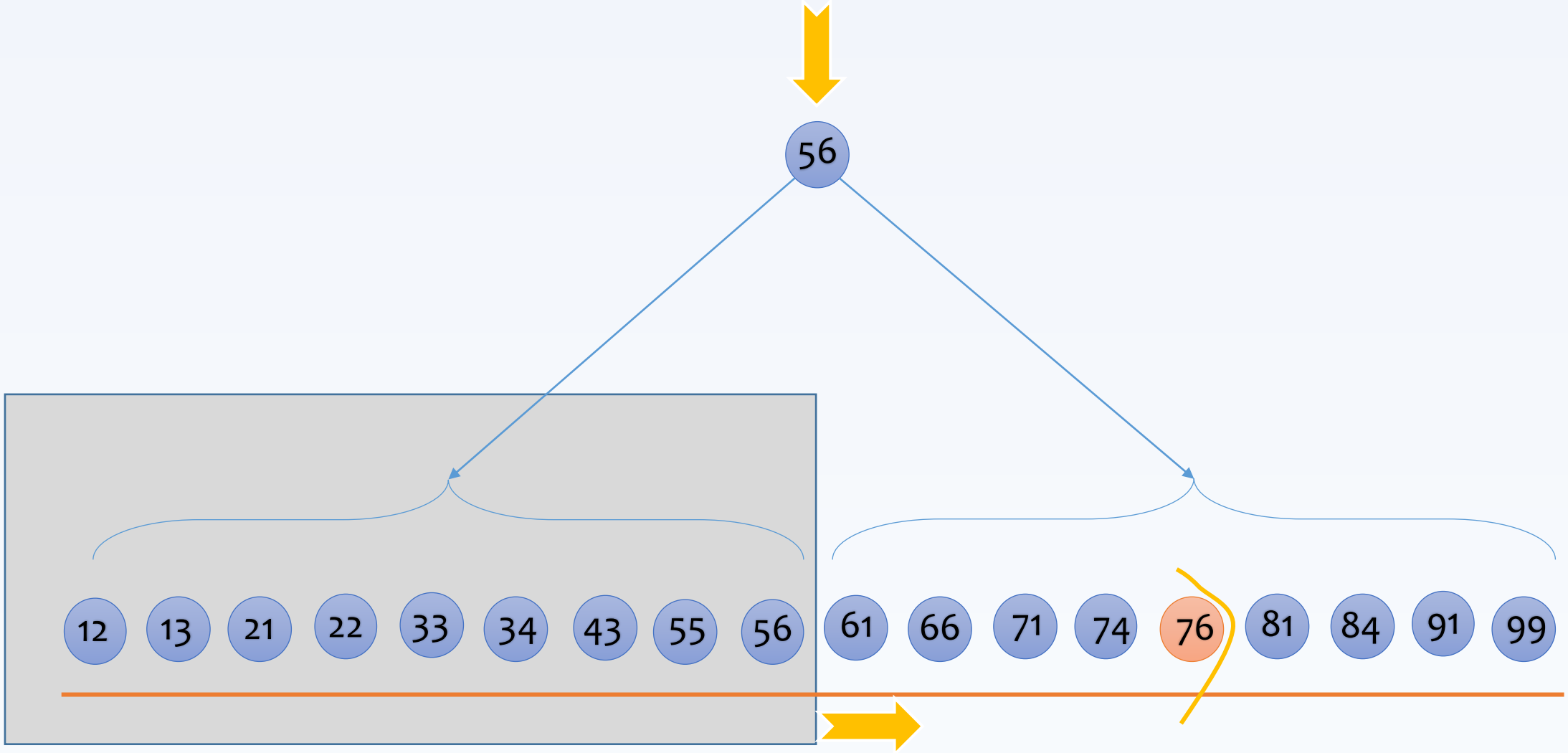
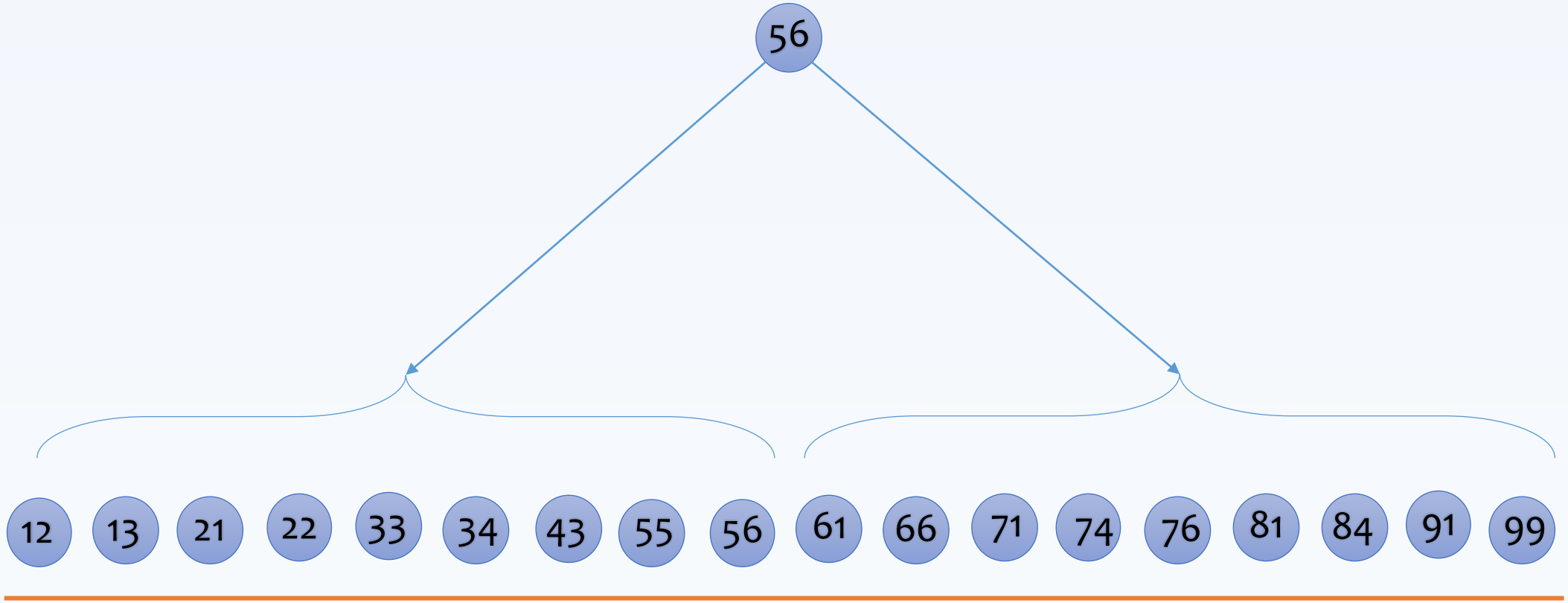
Searching for 76



Searching for 76

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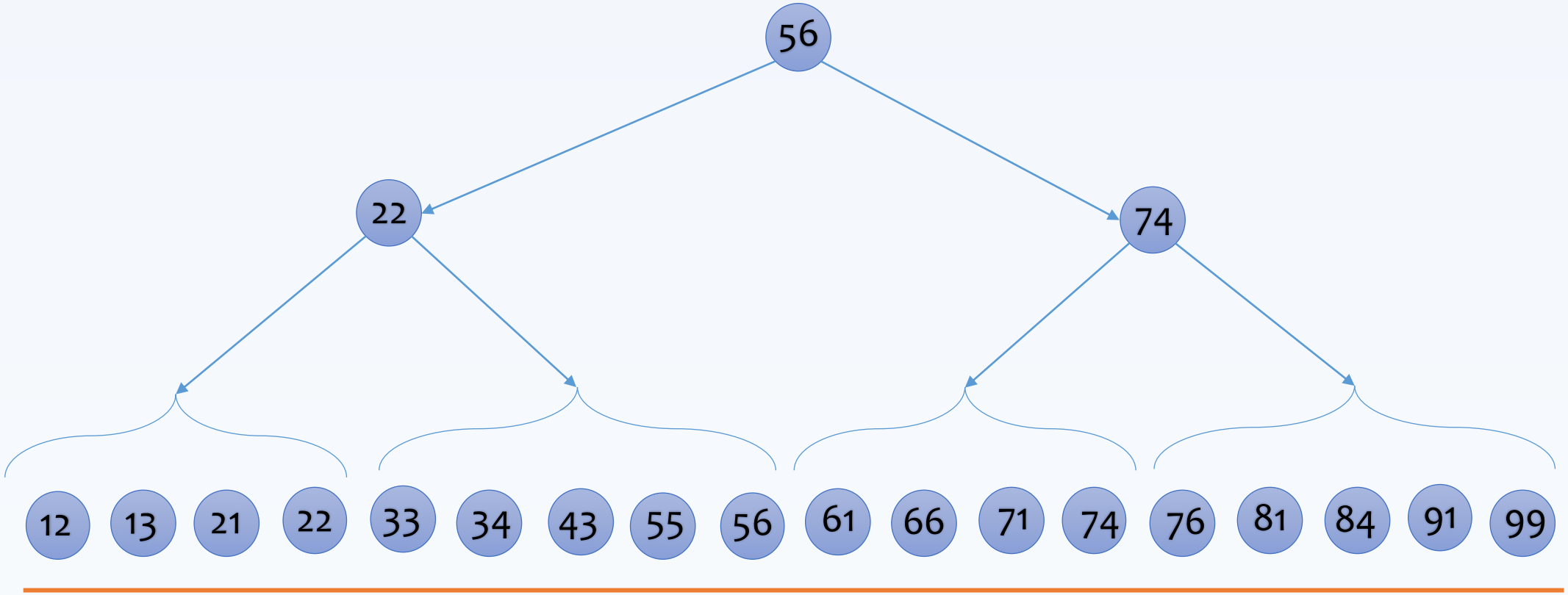
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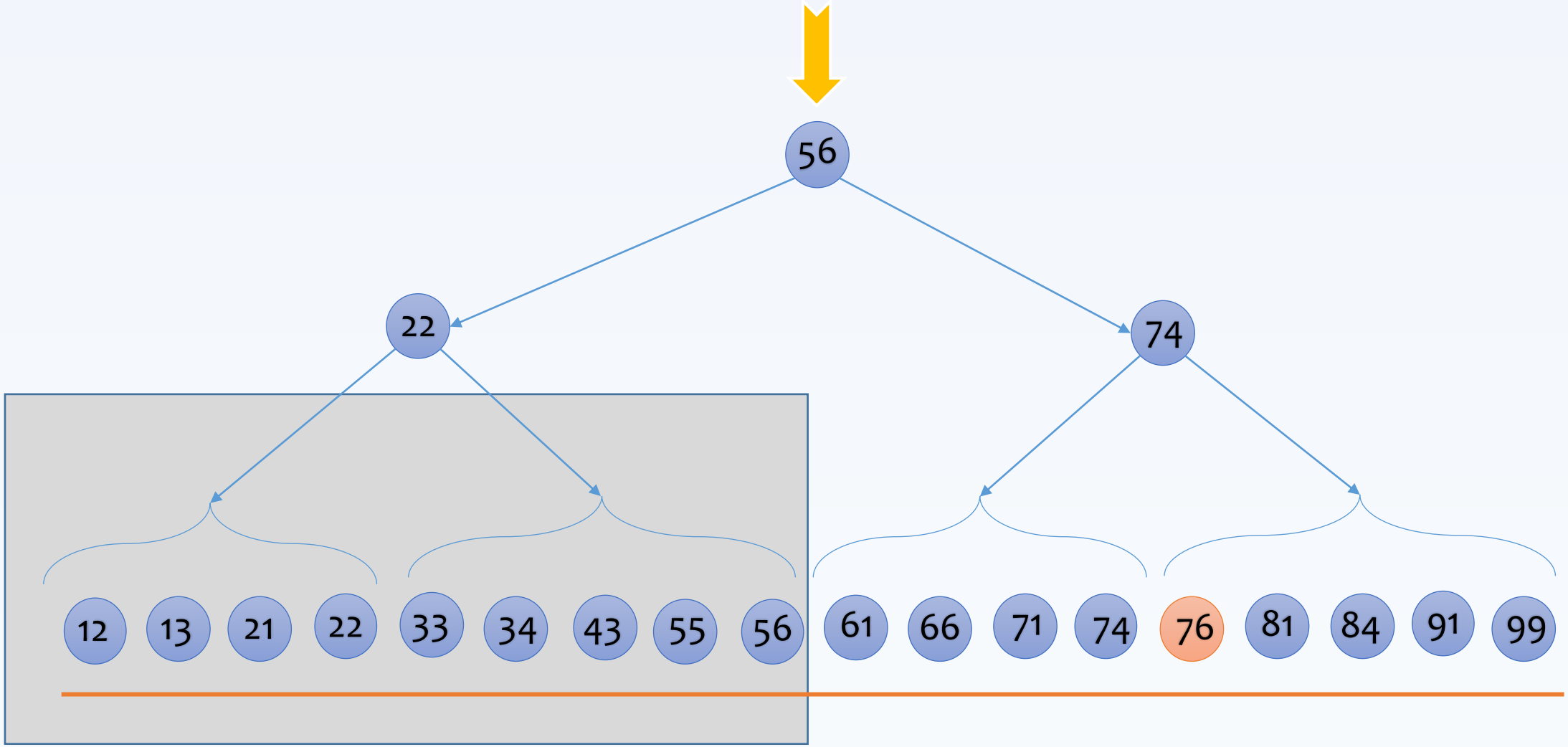
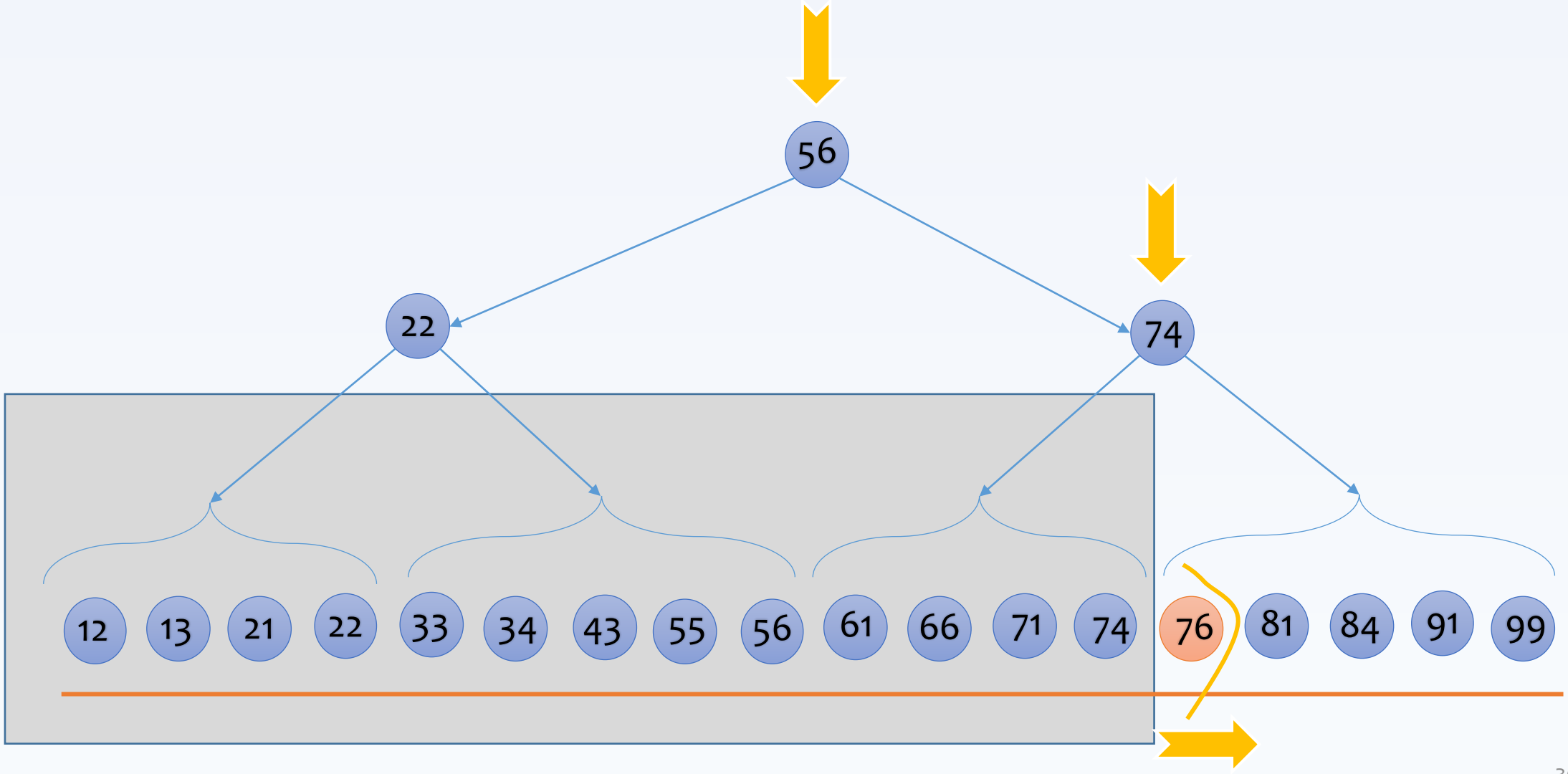
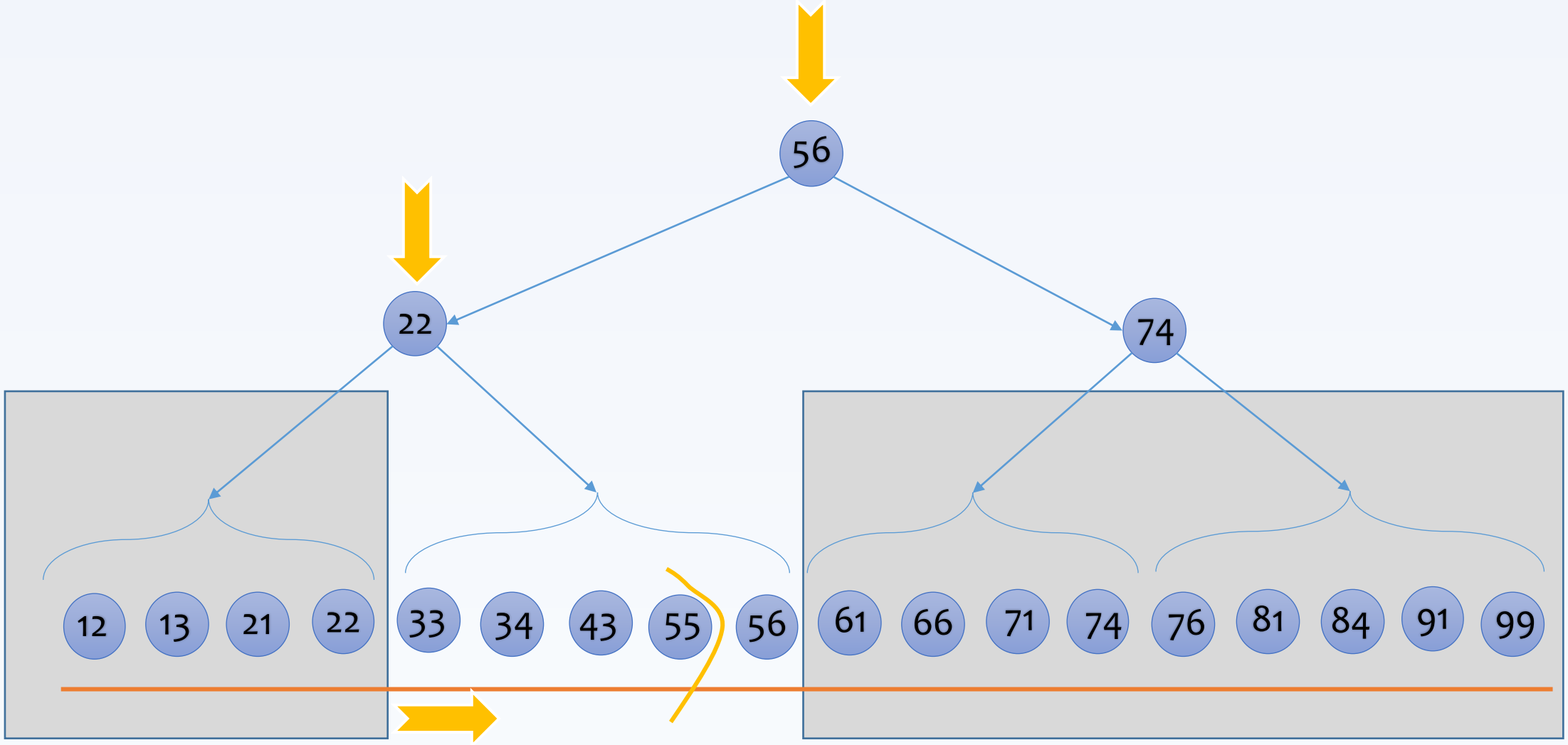
Searching for 76



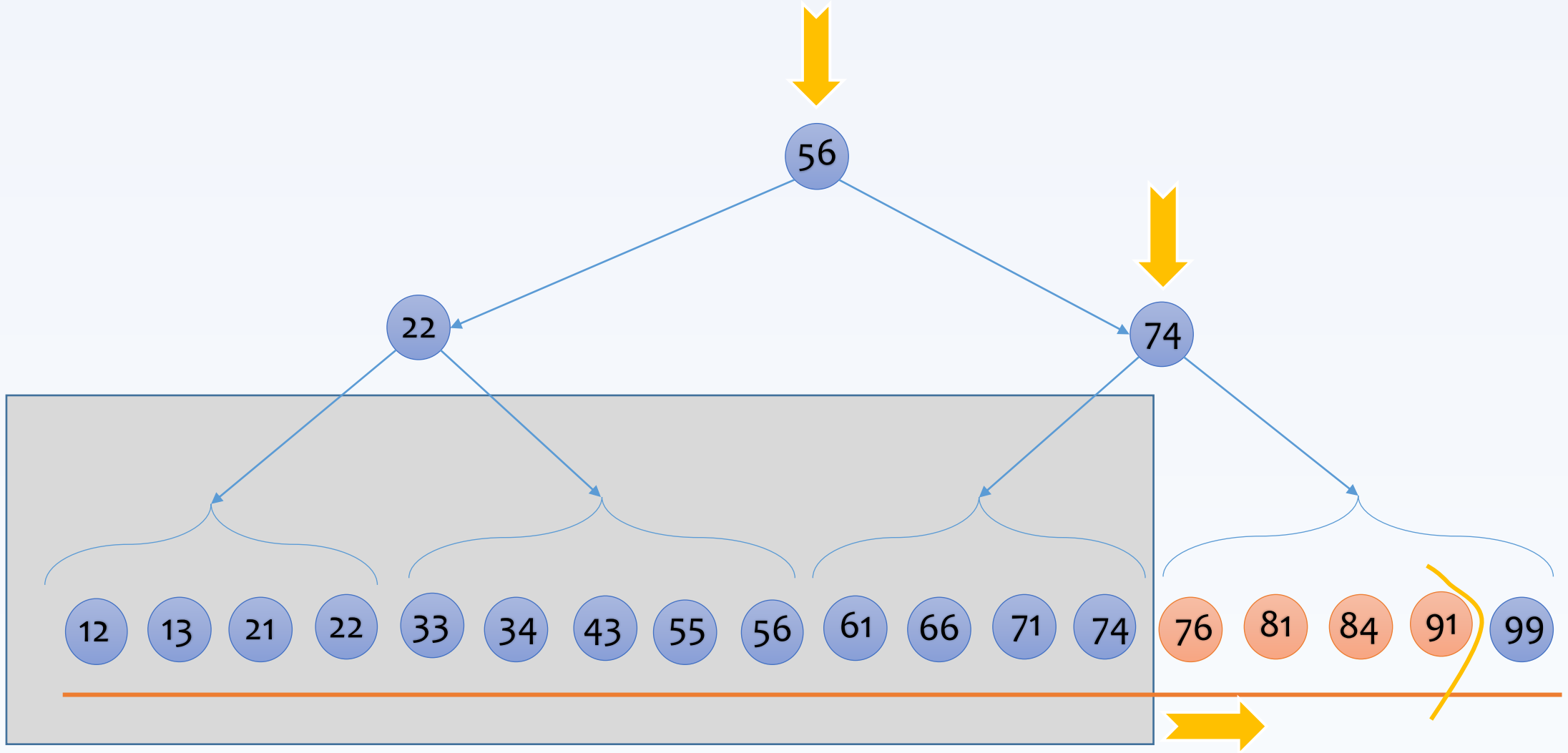
Searching for 76



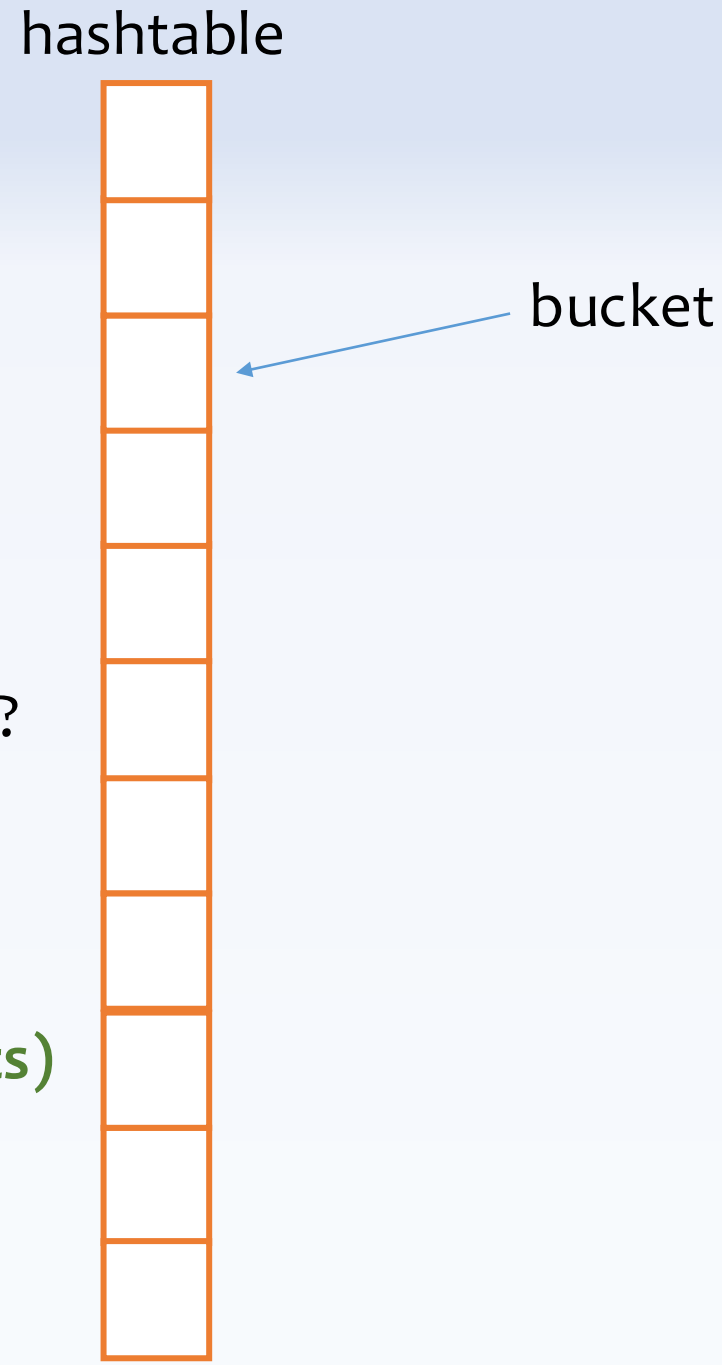
Searching for 44?
(could we have an early termination?)



Searching for 76-91



Could we spread the data cleverly to improve the search?



Hashing ( ) = ?

(returns a value between 1 to n, where n is the number of buckets)

Inserting 81

Hashing (81) = 6

Inserting 43

Hashing (43) = 10

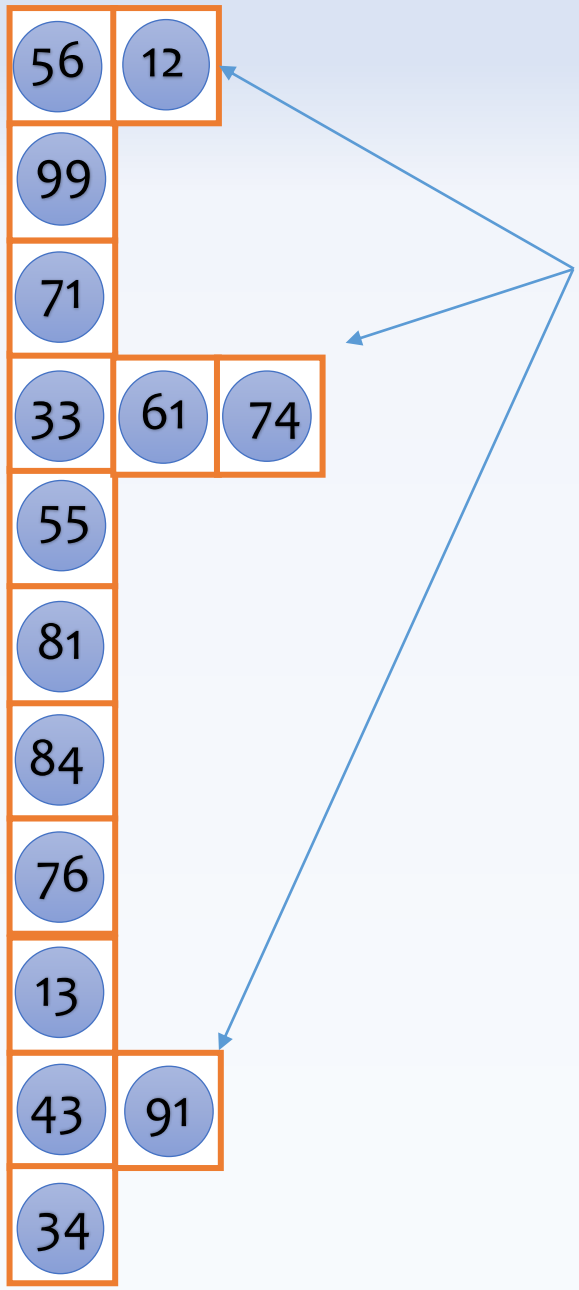
Inserting 76

Hashing (76) = 8

Inserting 91

Hashing (91) = 10

collisions
(when multiple values
hash to the same bucket)



collisions
(when multiple values
hash to the same bucket)

Searching for 76

(now we can have a constant lookup cost)

Hashing (76) = 8

Searching for 76-91?

Could we instead search for 76, 77, 78, …, 90, 91?

Hashing (76) = 8

Hashing (77) = 1

Hashing (78) = 3

Hashing (81) = 6

Hashing (84) = 7

Hashing (90) = 8

Hashing (91) = 10

Searching for 76-91

Could we instead search for 76, 77, 78, …, 90, 91?

Hashing (76) = 8

Hashing (77) = 1

Hashing (78) = 3

Hashing (81) = 6

Hashing (84) = 7

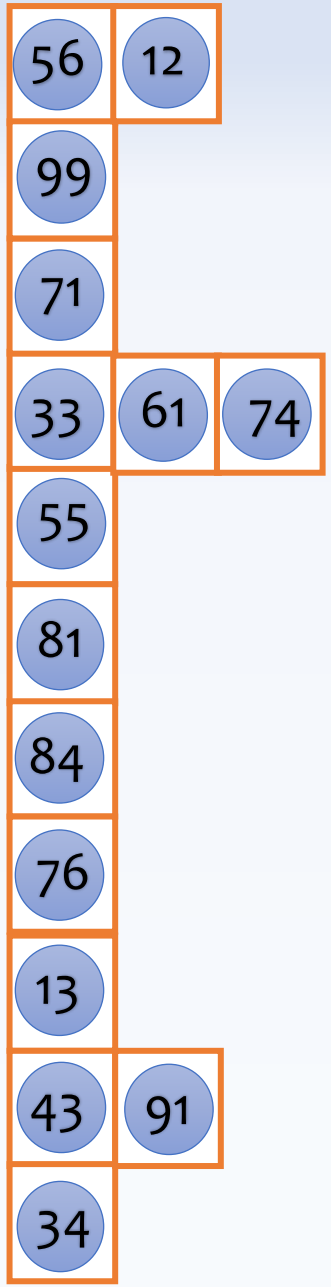
Hashing (90) = 8

Hashing (91) = 10

Searching for 76-91

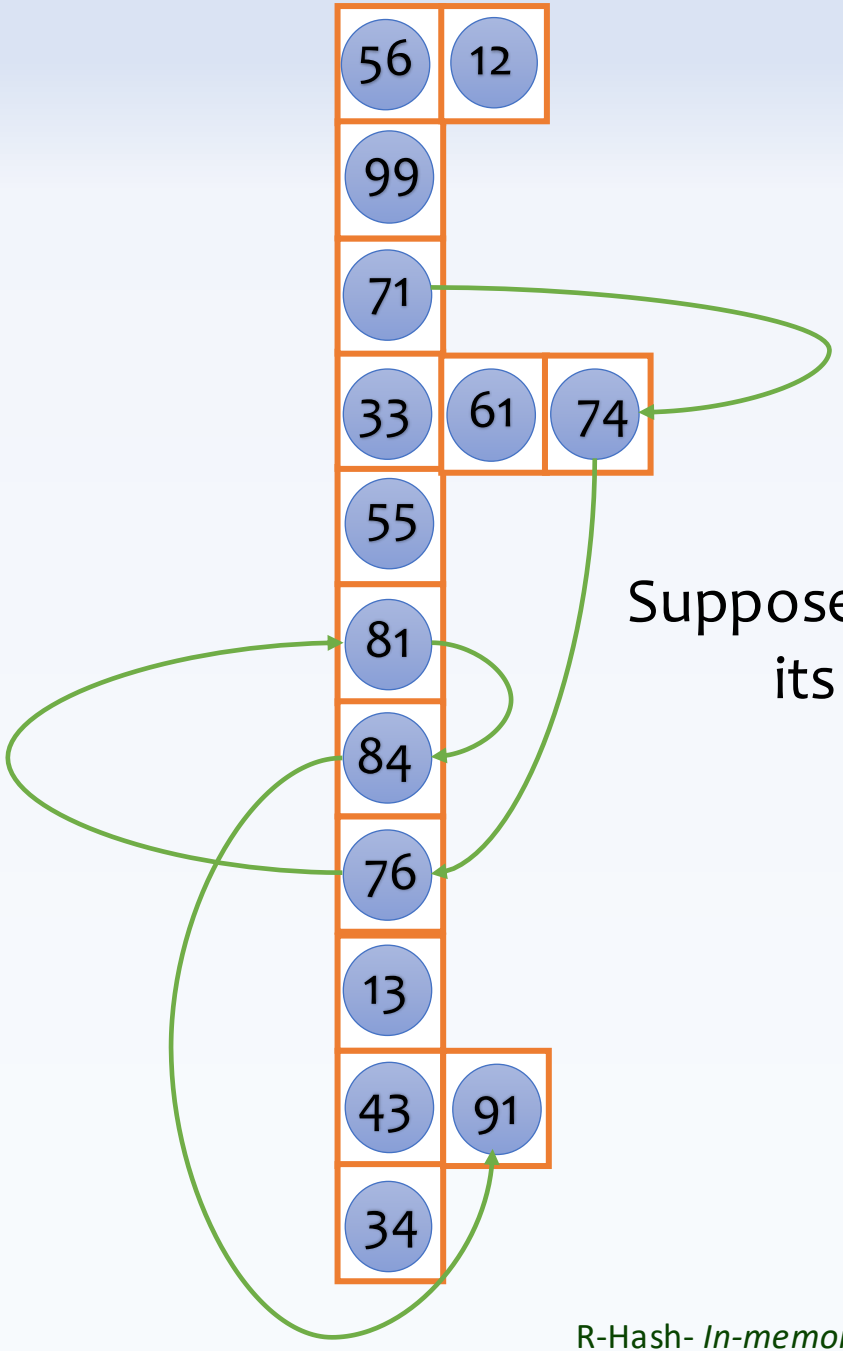
How about 76.01, 76.02, 76.03, …?
(simply not practical)

Could we imagine a new design to support searching for a range of values efficiently?



Let's promote a subset of values as seeds

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

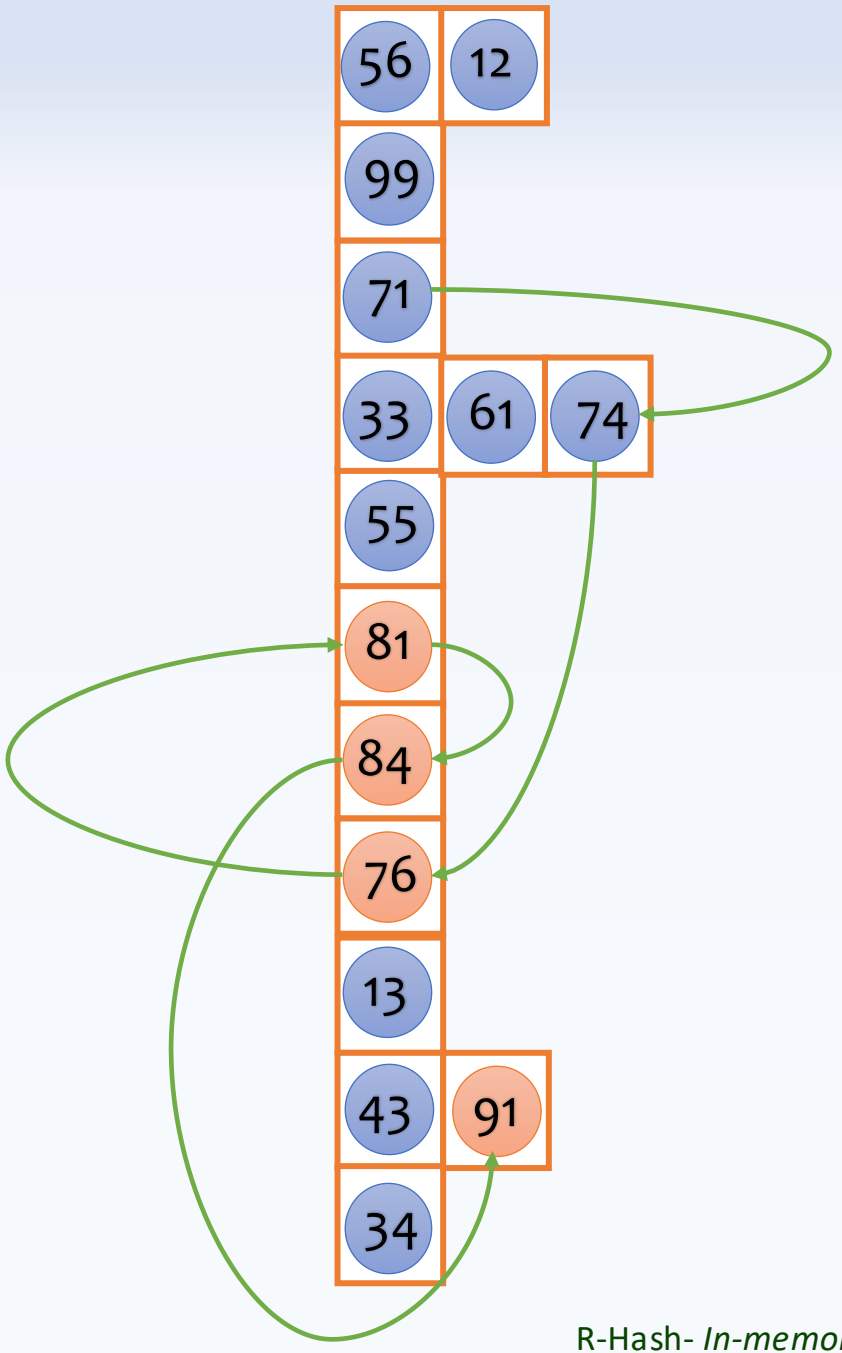


Let's promote a subset of values as seeds

Suppose every value points to its next larger value

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

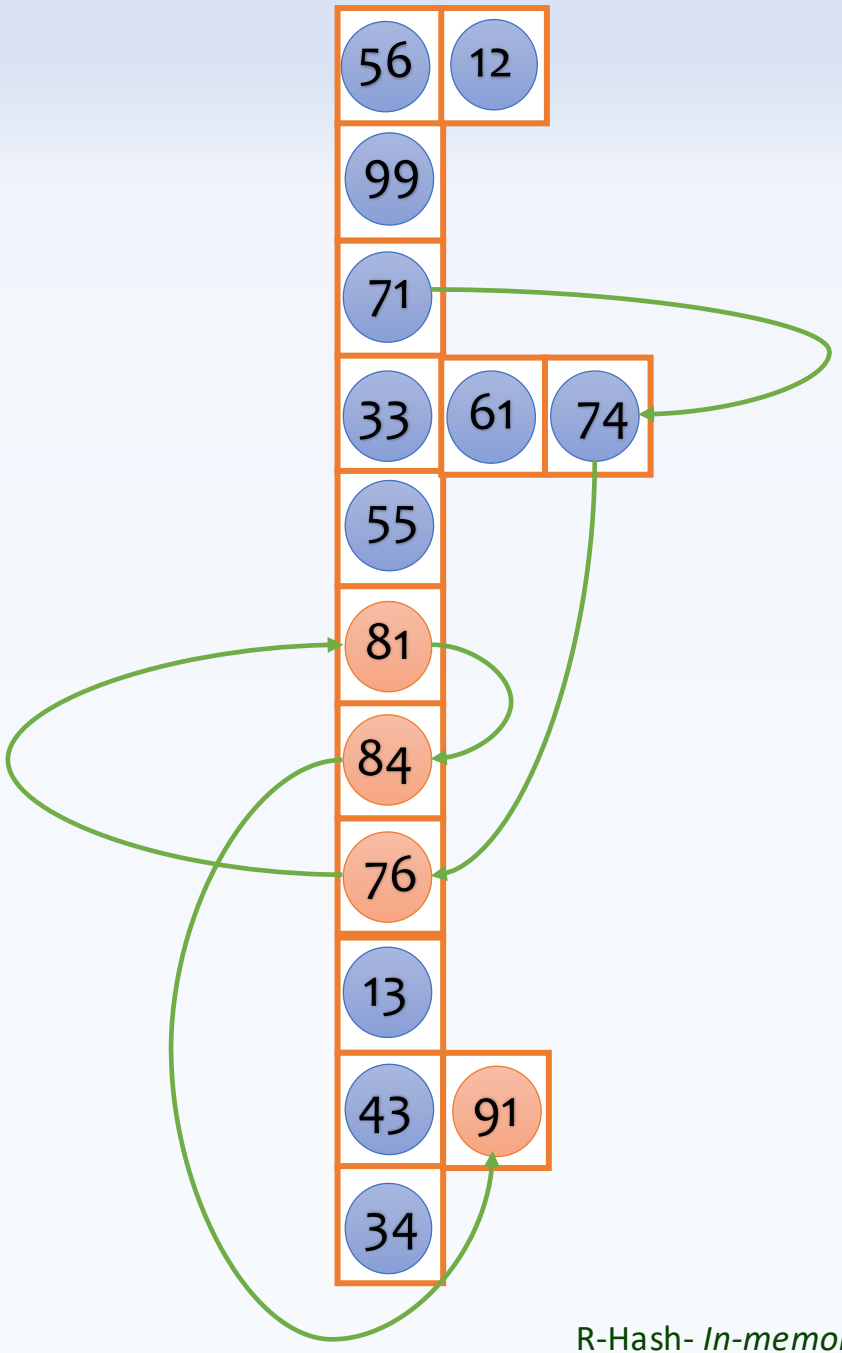
Searching for 76-91



sorted seeds

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

Searching for 76-91



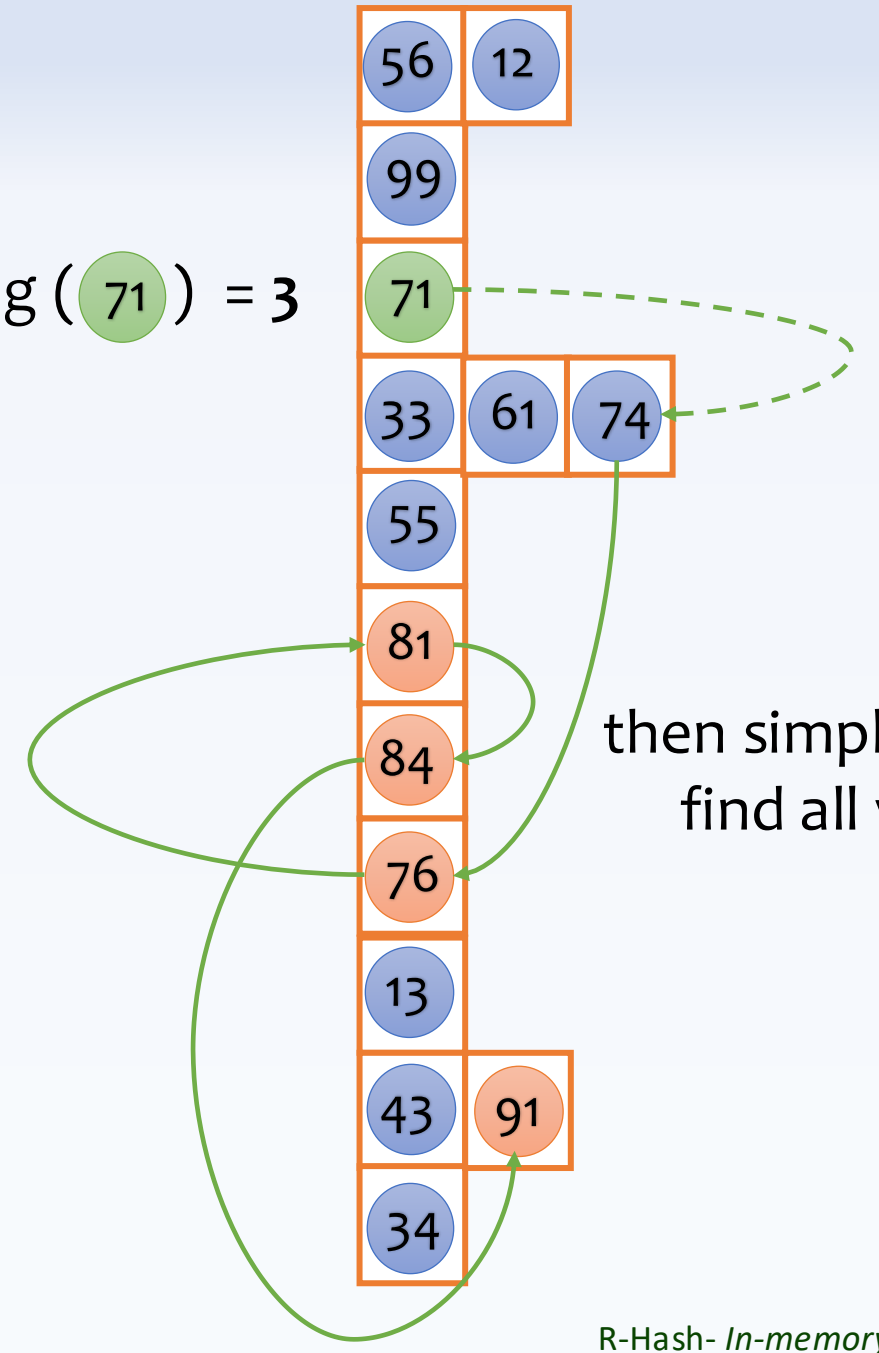
sorted seeds

Find the largest seed smaller than 76: 71

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

Searching for 76-91

Hashing (71) = **3**



sorted seeds

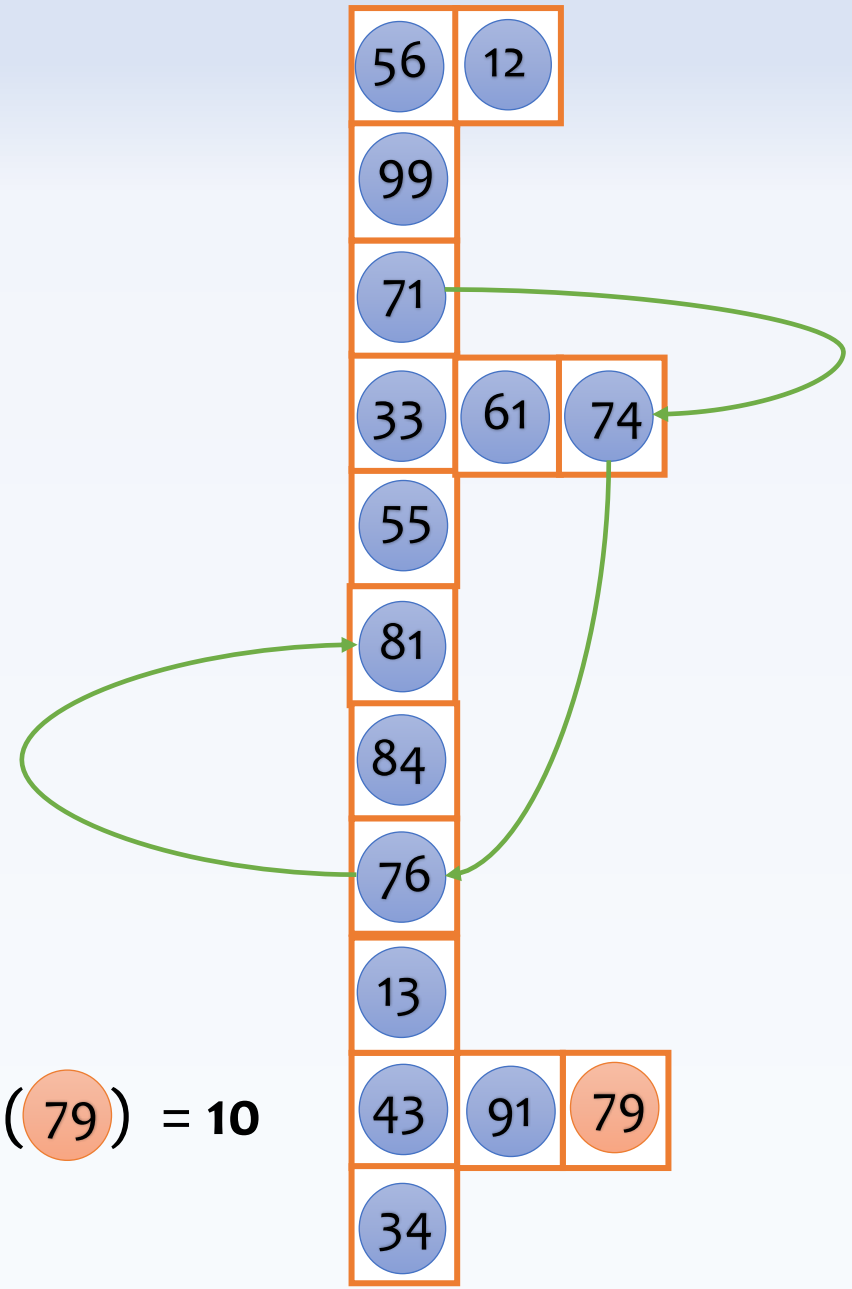
34 71 91

Find the largest seed smaller than 76: 71

then simply follow the pointers to find all values between 76-91

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

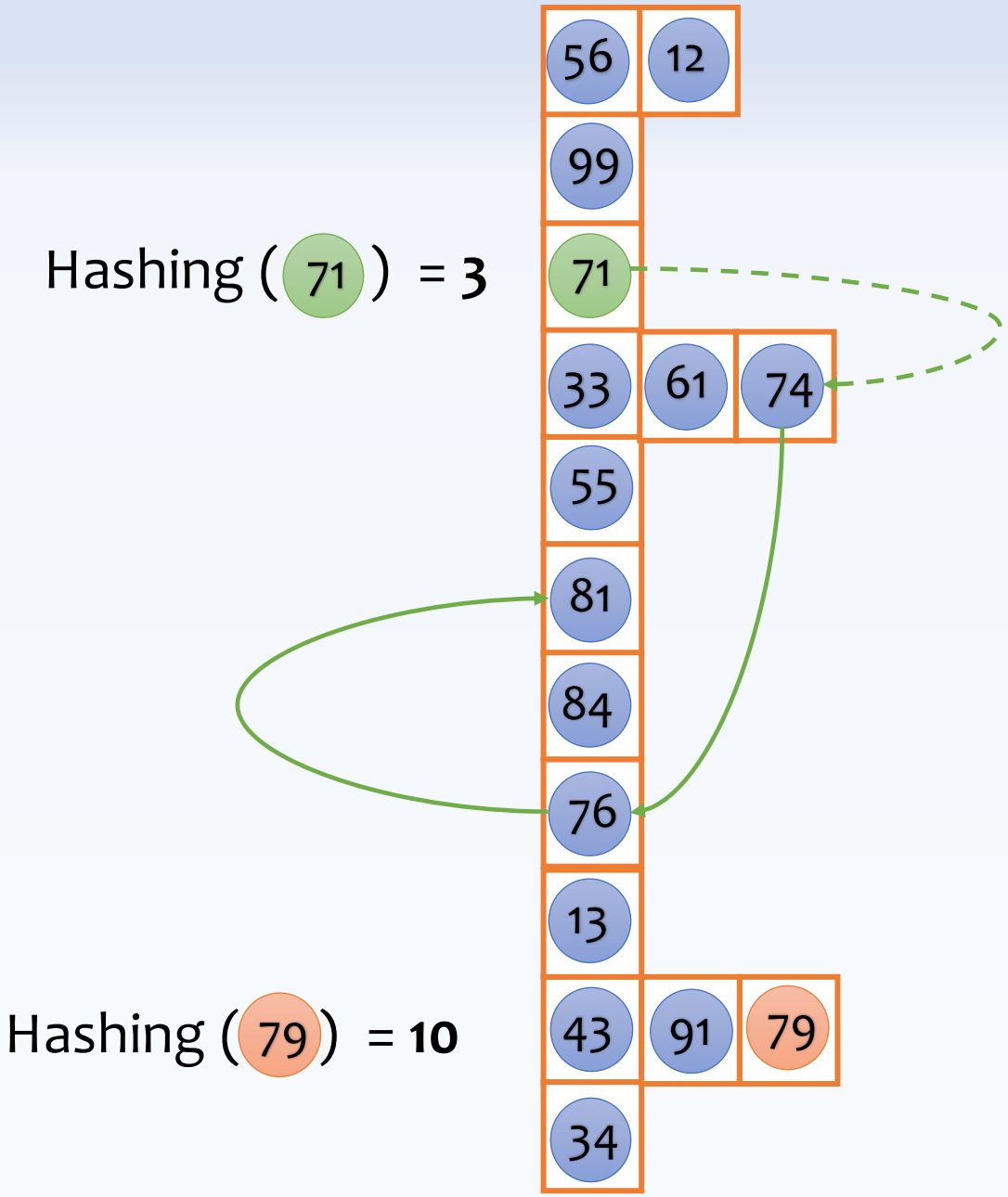
Inserting 79



Hashing (79) = **10**

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

Inserting 79



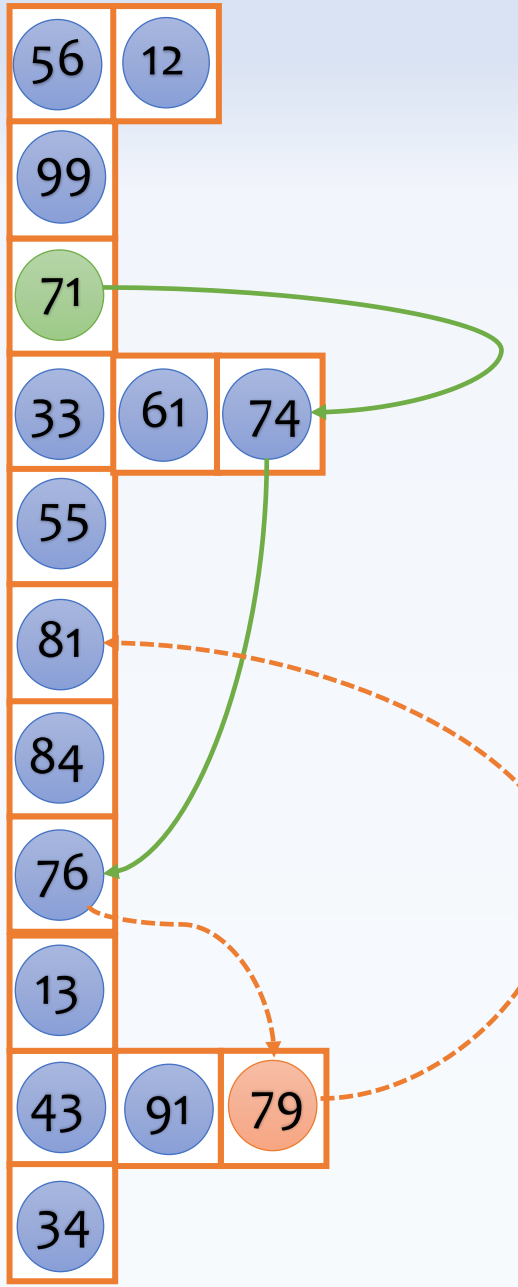
sorted seeds

34 71 91

Find the largest seed smaller than 79: 71

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

Inserting 79



Hashing (71) = **3**

Hashing (79) = **10**

sorted seeds

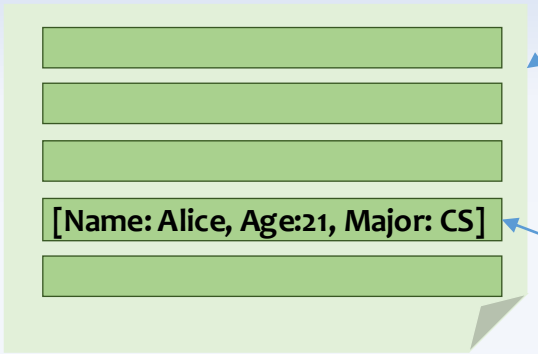
34 71 91

Find the largest seed smaller than 79: 71

adjust the pointers accordingly

R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

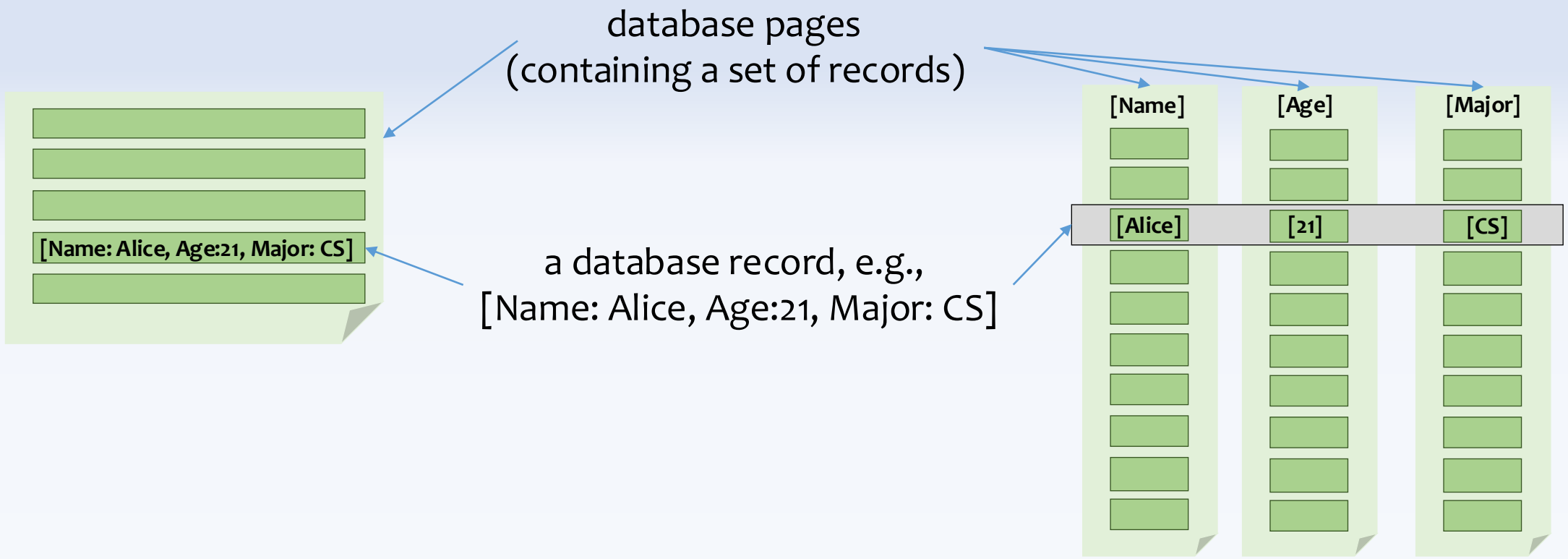
Database Storage Layouts
(how likely that we need an index for range queries?)



database pages
(containing a set of records)

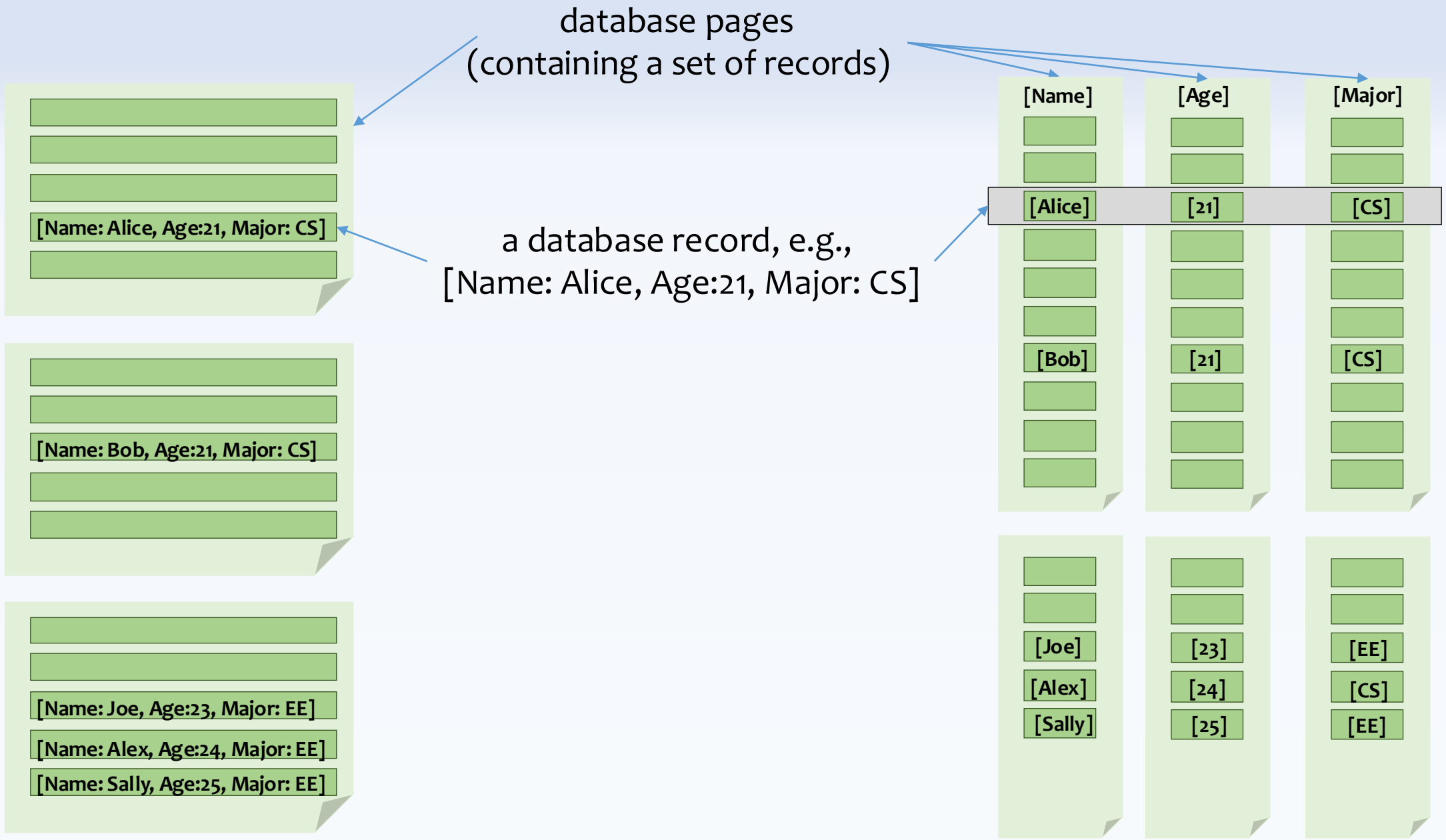
a database record, e.g.,
[Name: Alice, Age:21, Major: CS]

Row-based Layout



Row-based Layout

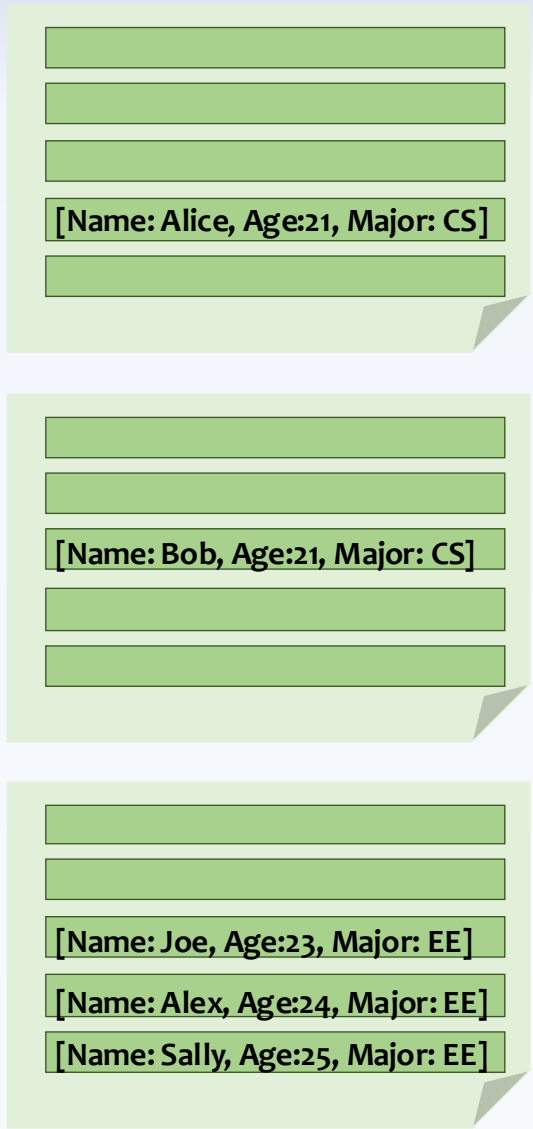
Column-based Layout



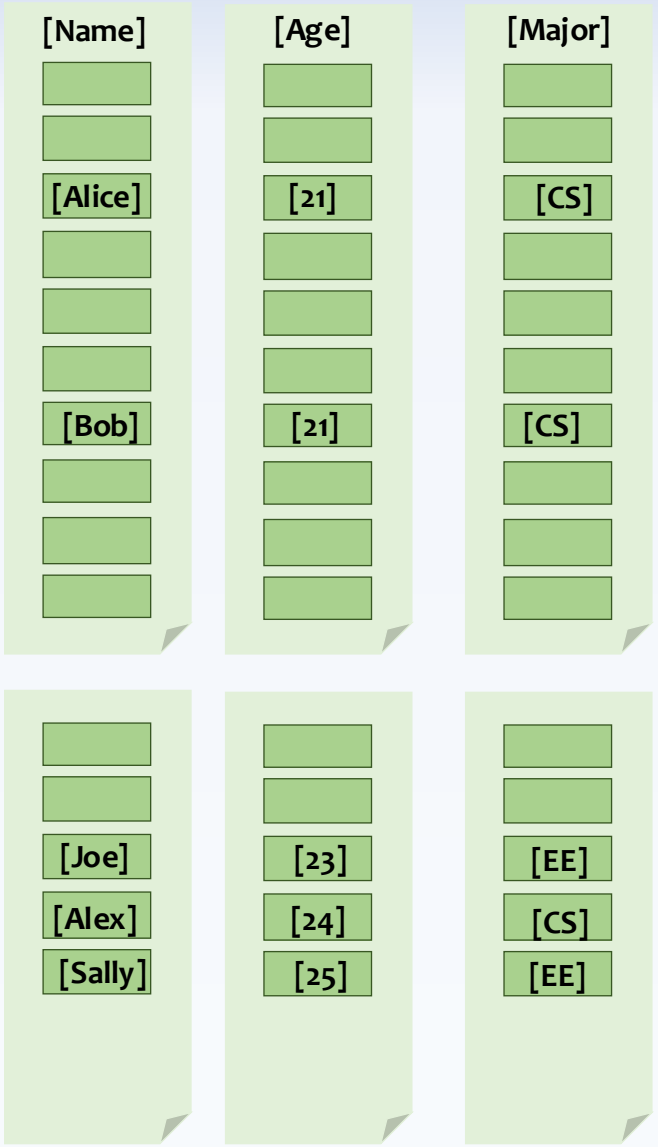
Row-based Layout

Column-based Layout

Searching for all students between the age of 21 to 24 (may return many students)

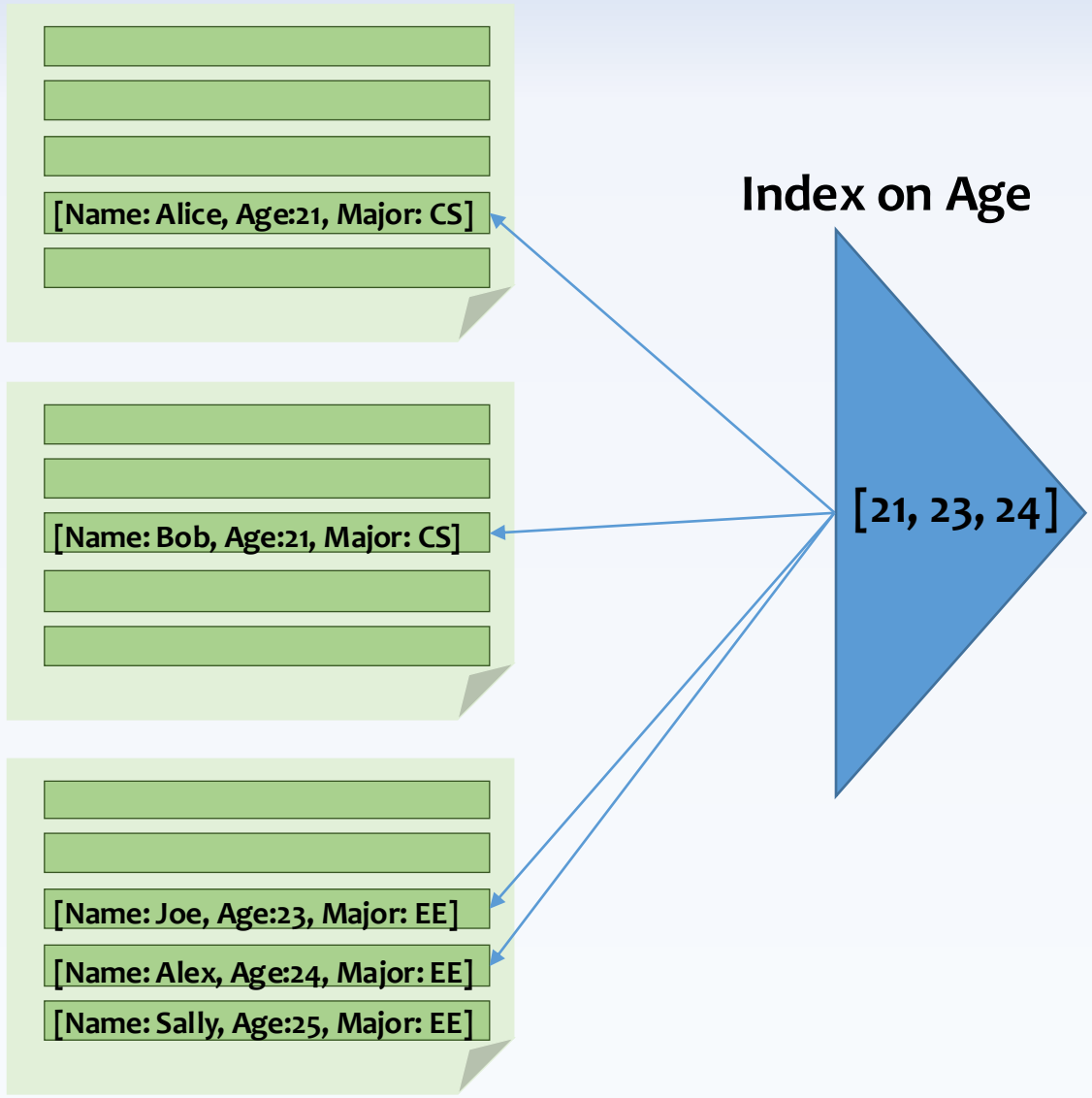


Row-based Layout

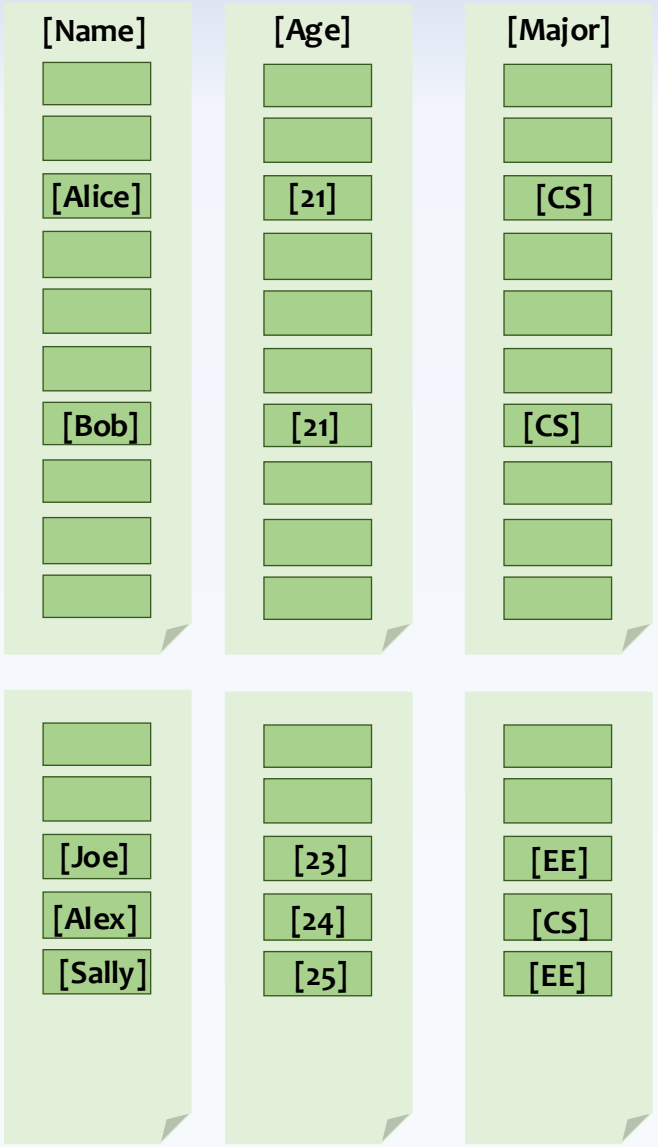


Column-based Layout

Searching for all students between the age of 21 to 24 (may return many students)

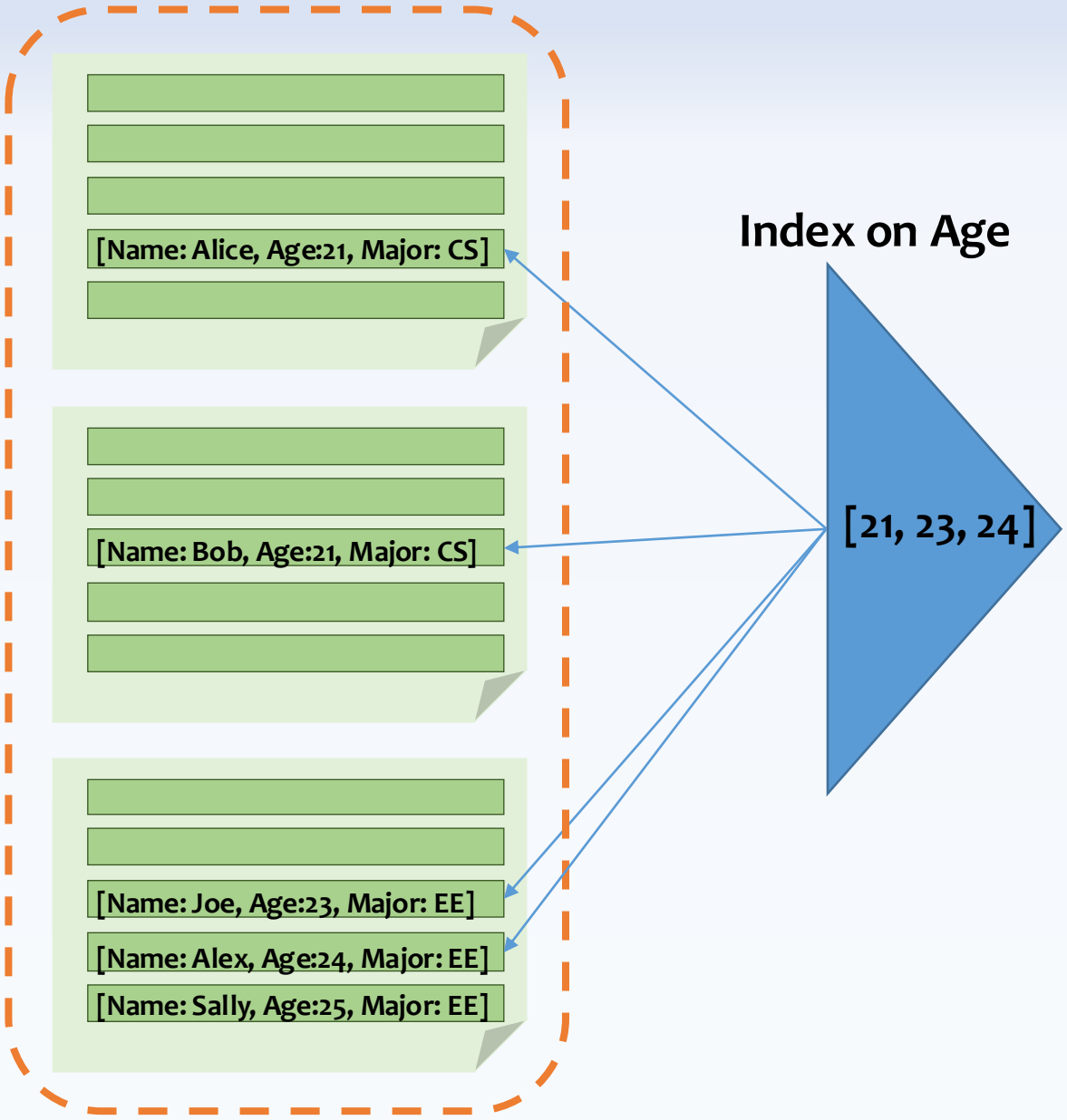


Row-based Layout

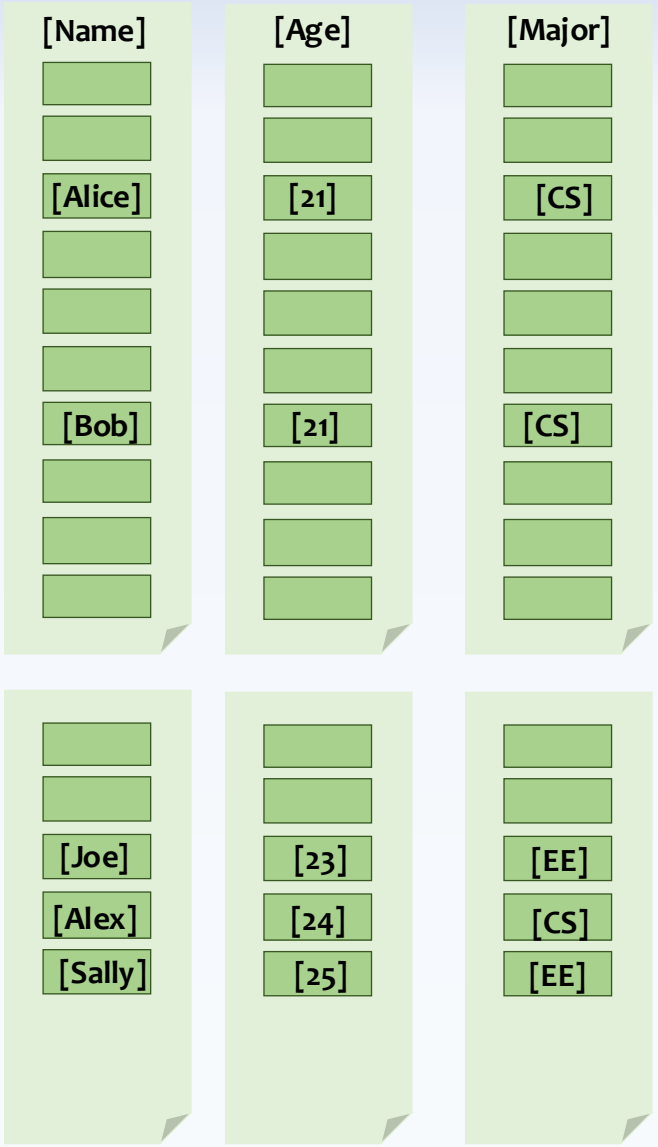


Column-based Layout

Searching for all students between the age of 21 to 24 (may return many students)

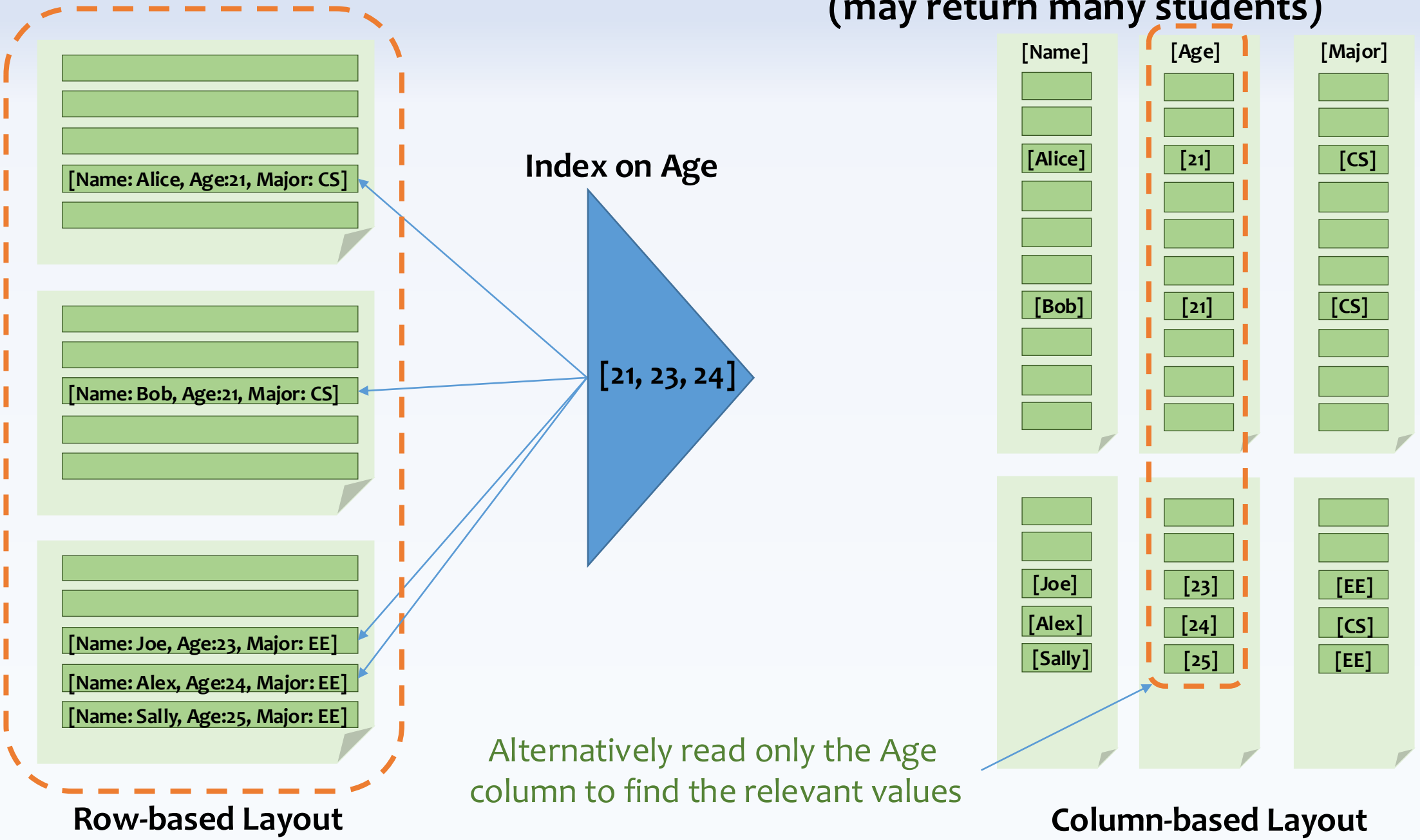


Row-based Layout

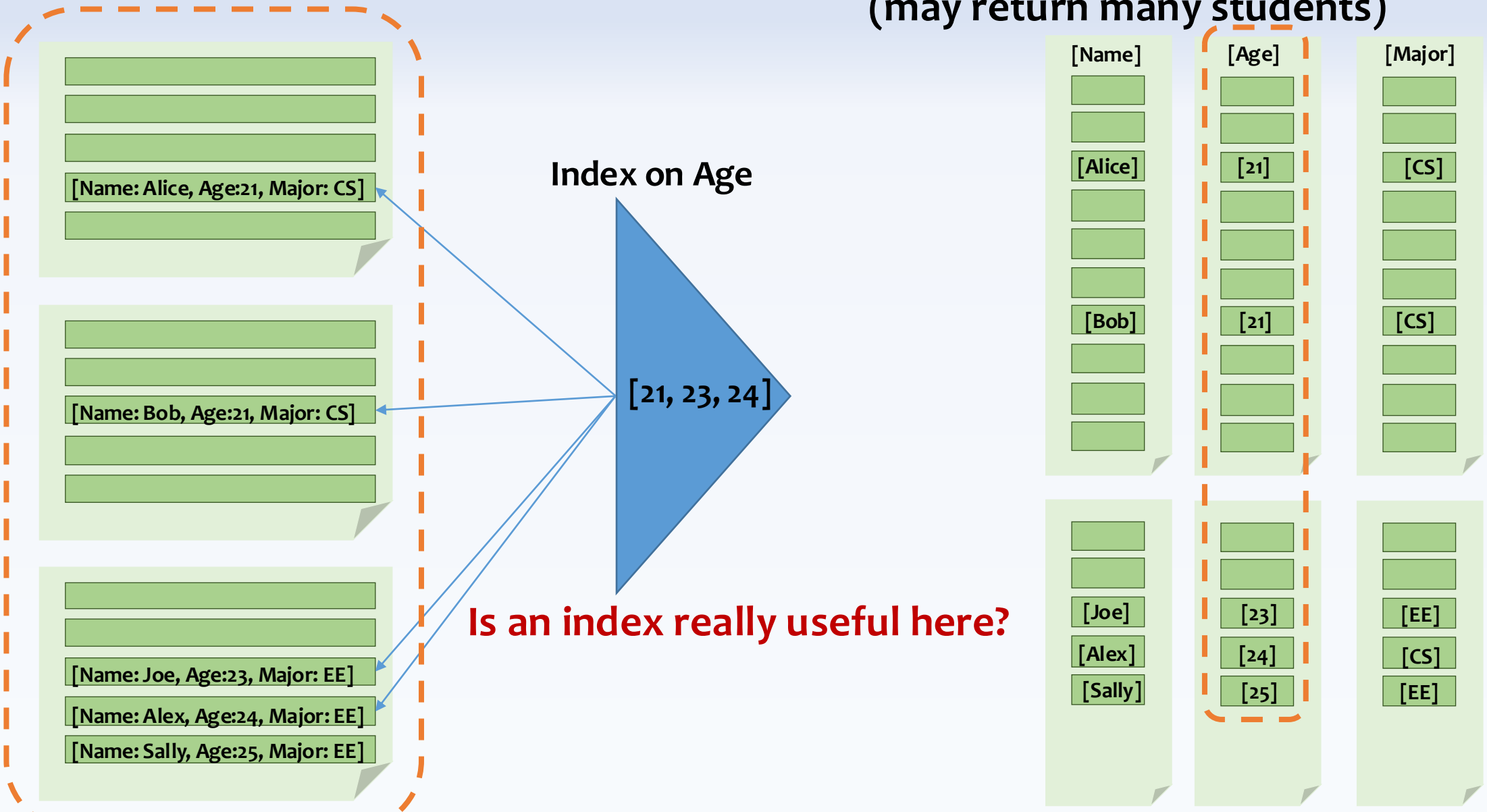


Column-based Layout

Searching for all students between the age of 21 to 24 (may return many students)



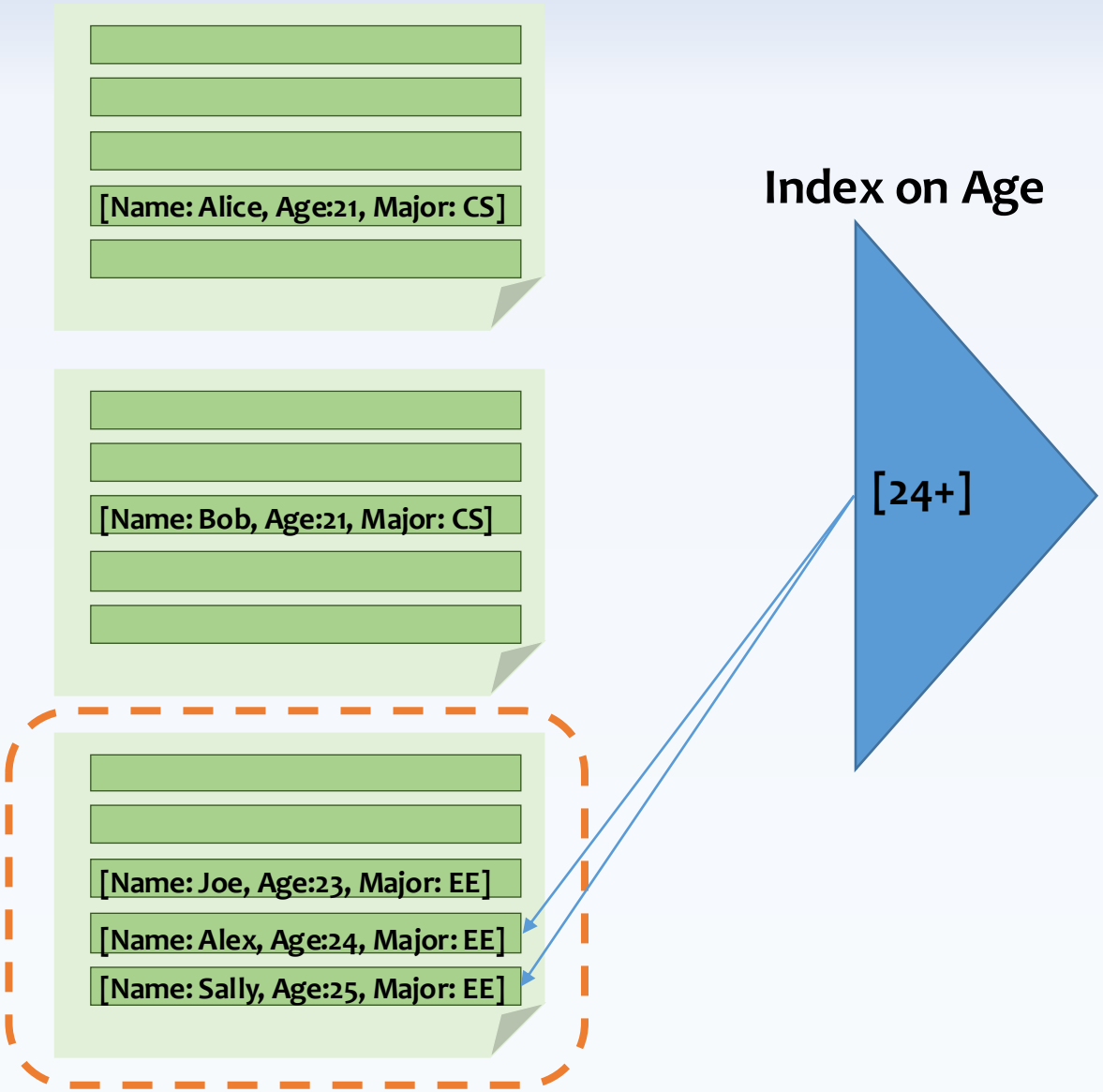
Searching for all students between the age of 21 to 24 (may return many students)

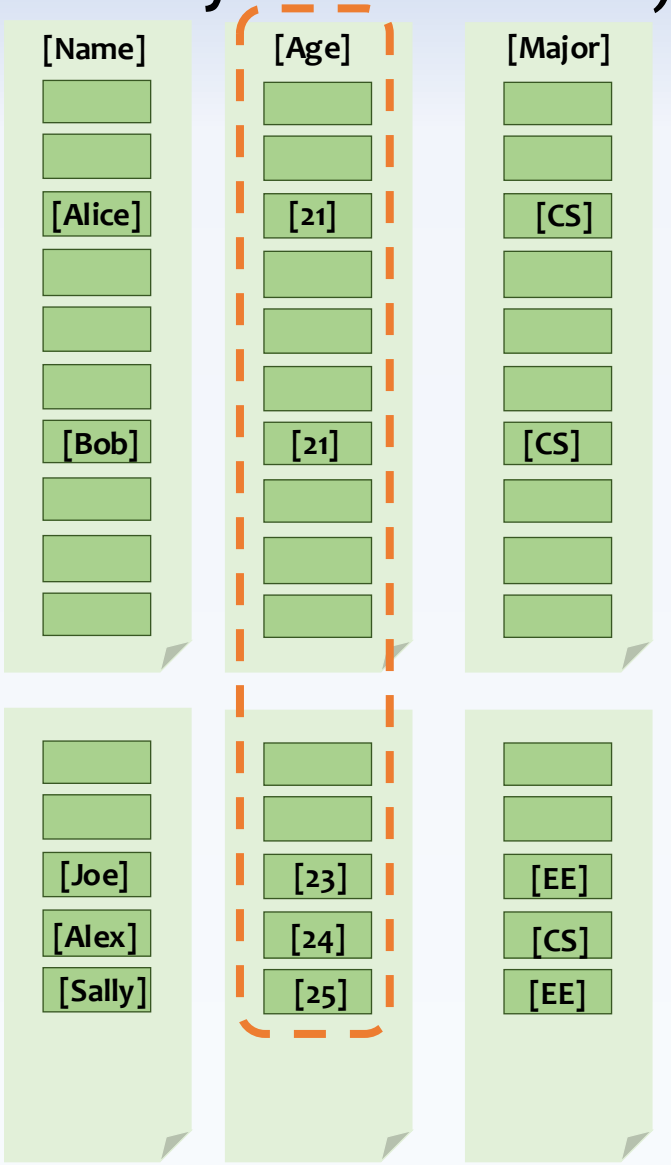


Row-based Layout

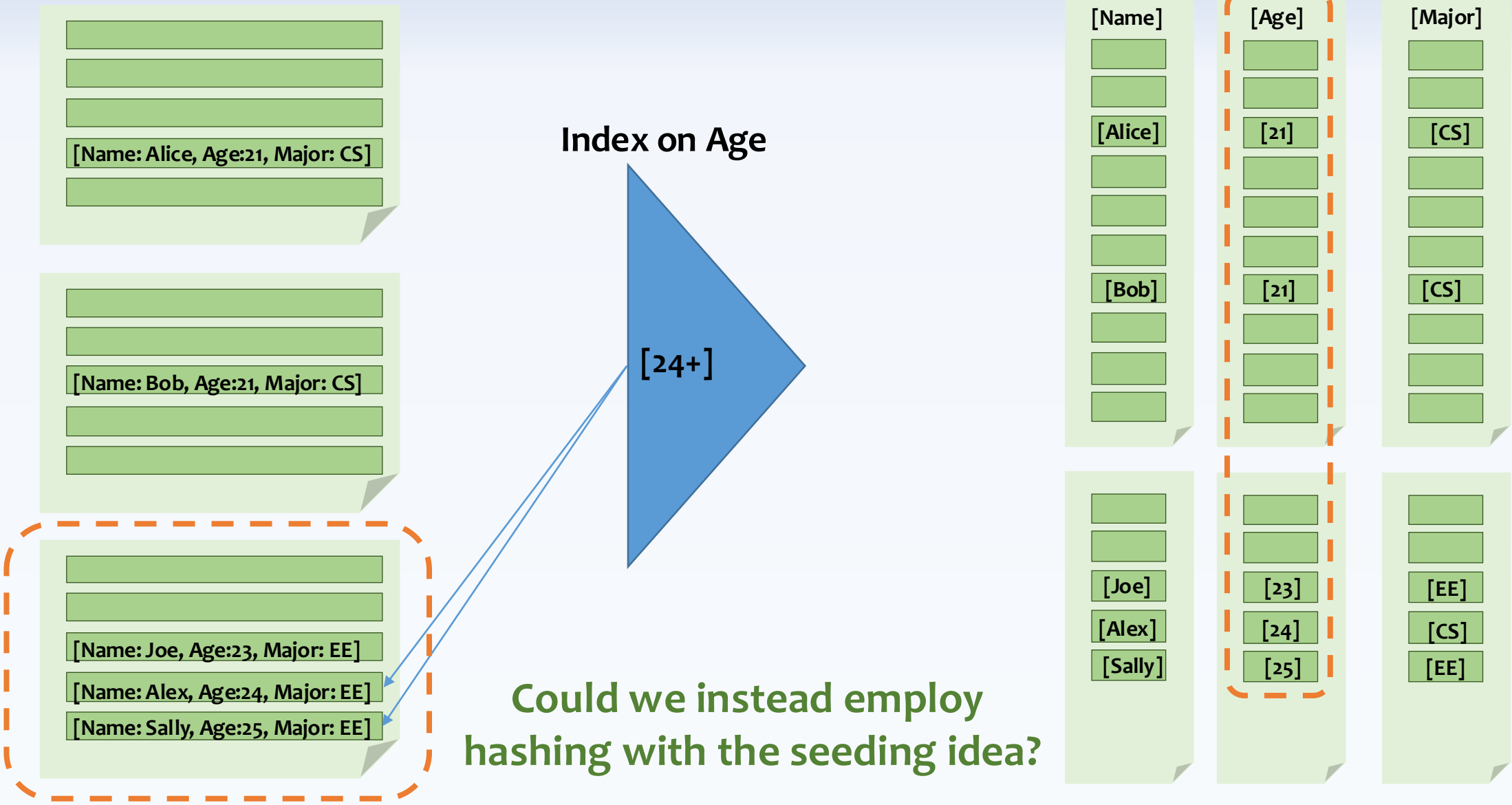
Column-based Layout

Searching for all students over the age of 24 (may return only a few students)





Searching for all students over the age of 24 (may return only a few students)



Could we instead employ hashing with the seeding idea?

Row-based Layout

Column-based Layout

Thank You
Questions?