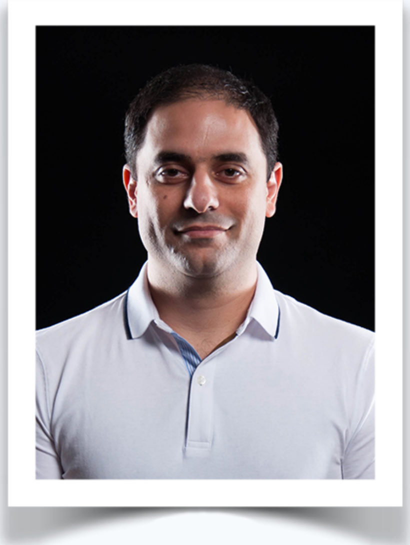
Storage & Indexing in Modern Databases

ECS 165A – Winter 2022



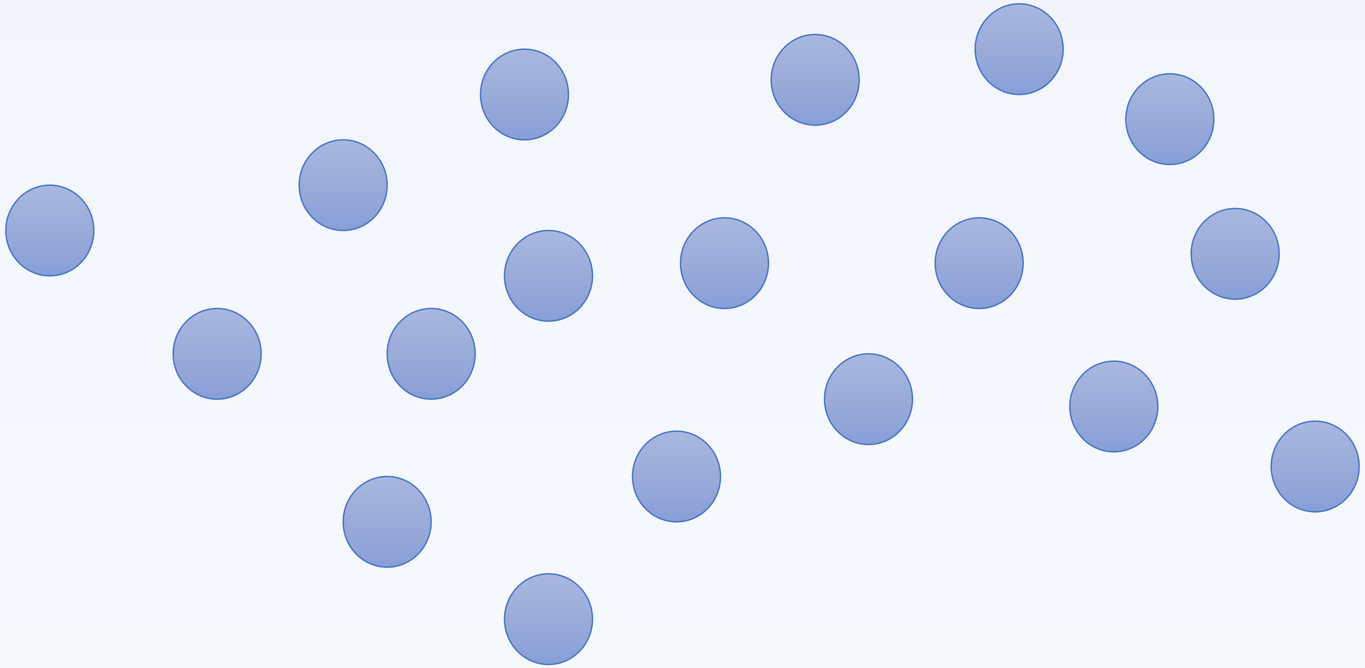
Mohammad Sadoghi
Exploratory Systems Lab
Department of Computer Science

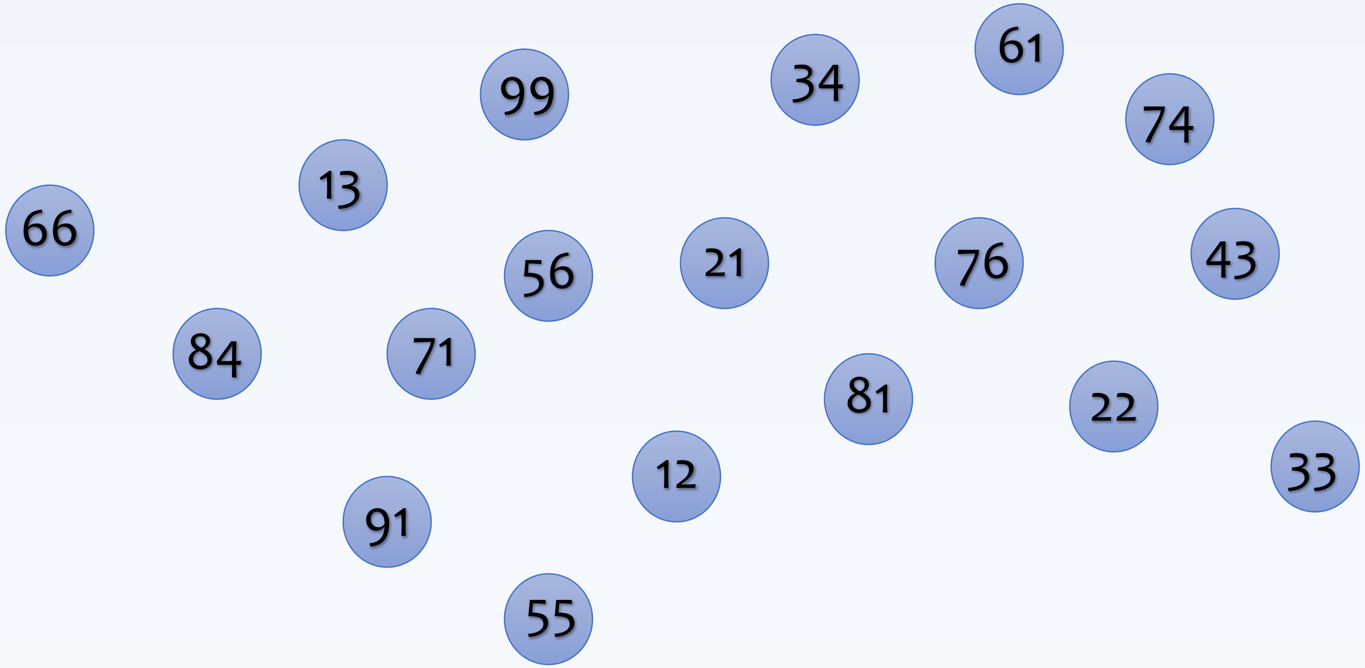
UCDAVIS
UNIVERSITY OF CALIFORNIA

ExpoLab
Creativity Unfolded

ResilientDB

How to quickly search for the desired information?





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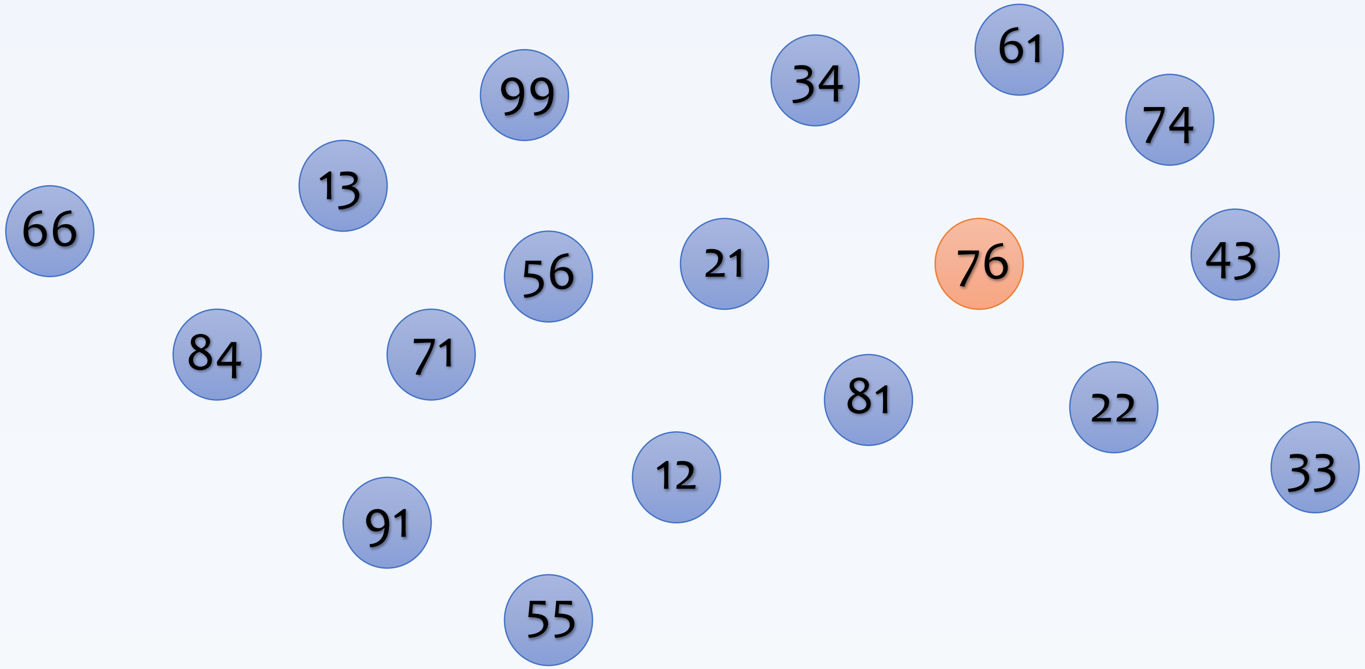
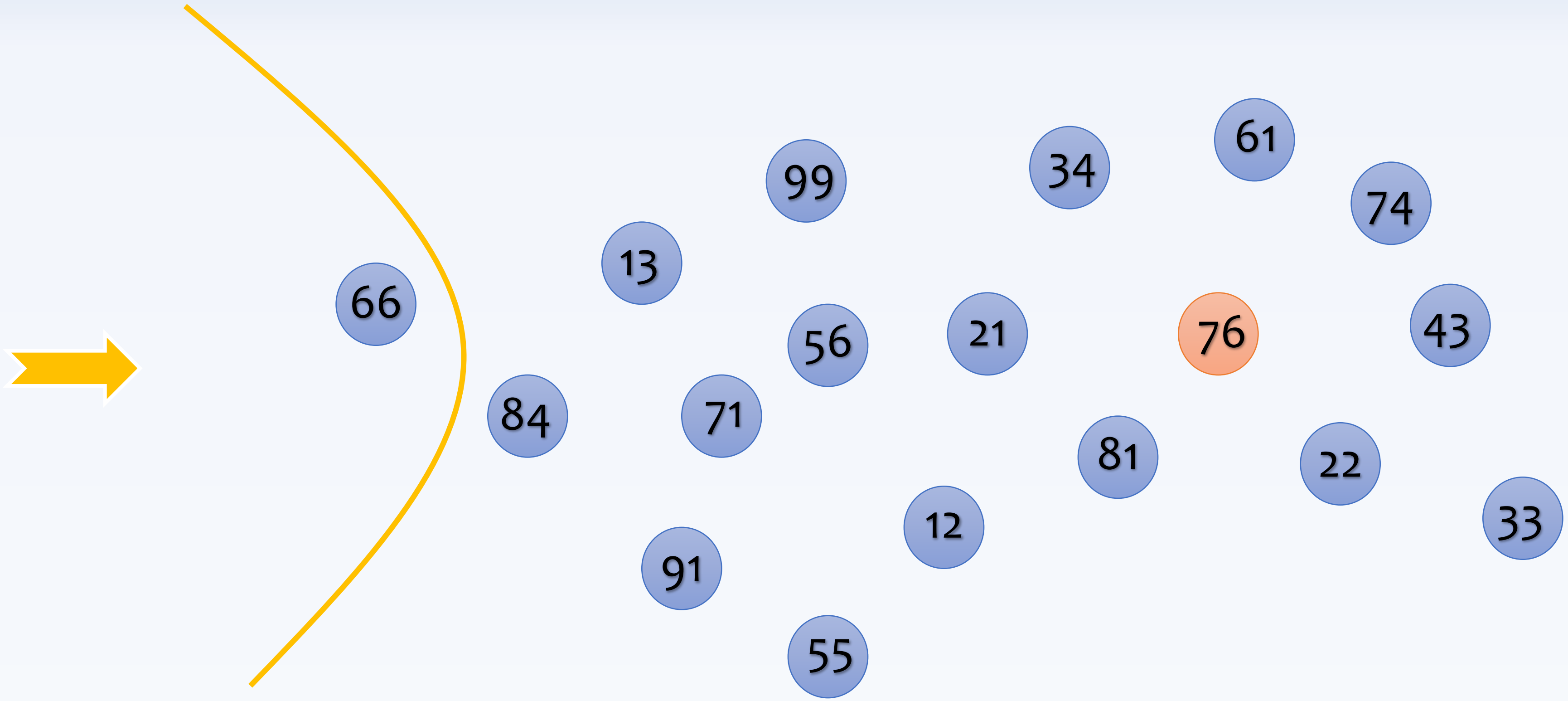
Searching for 76



Searching for 76



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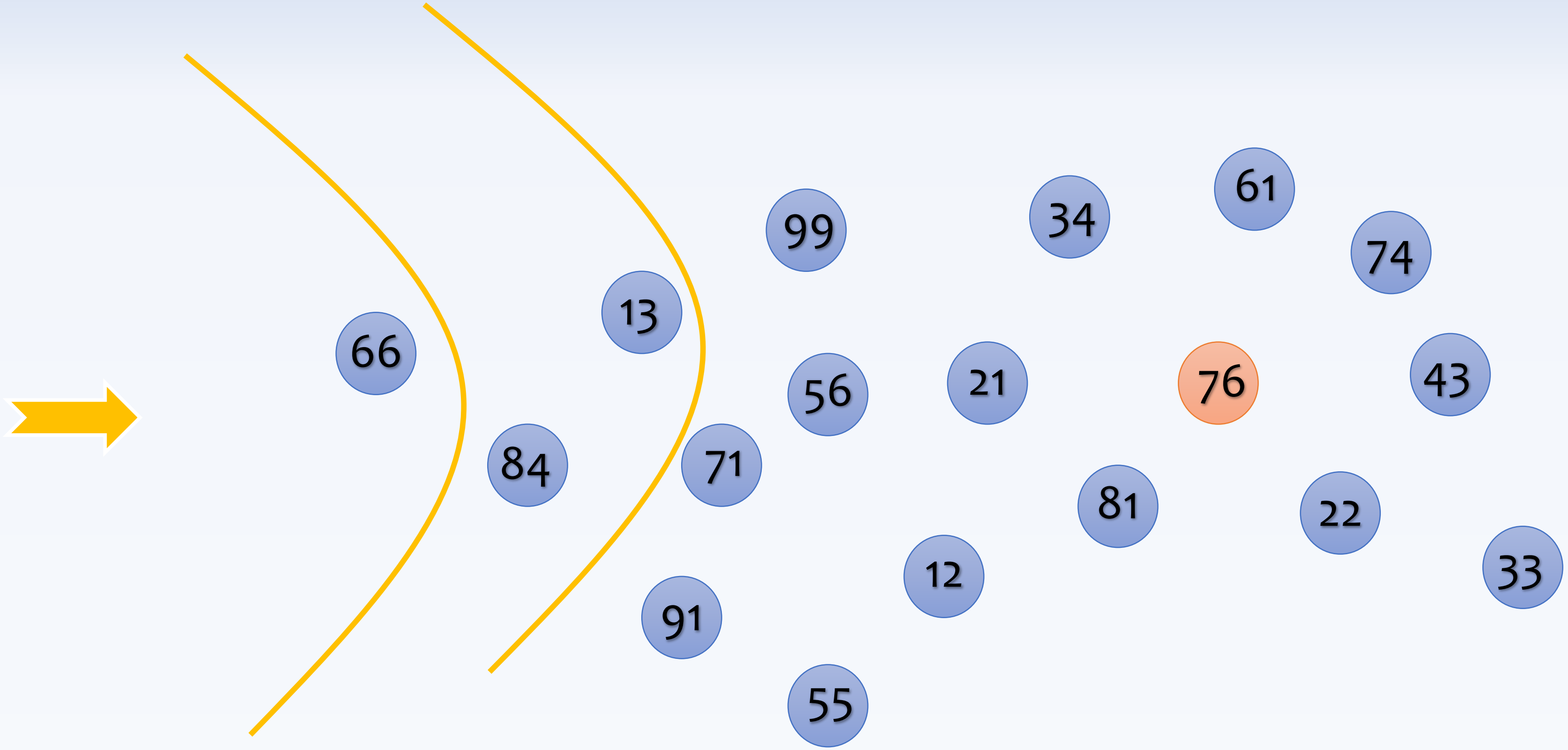

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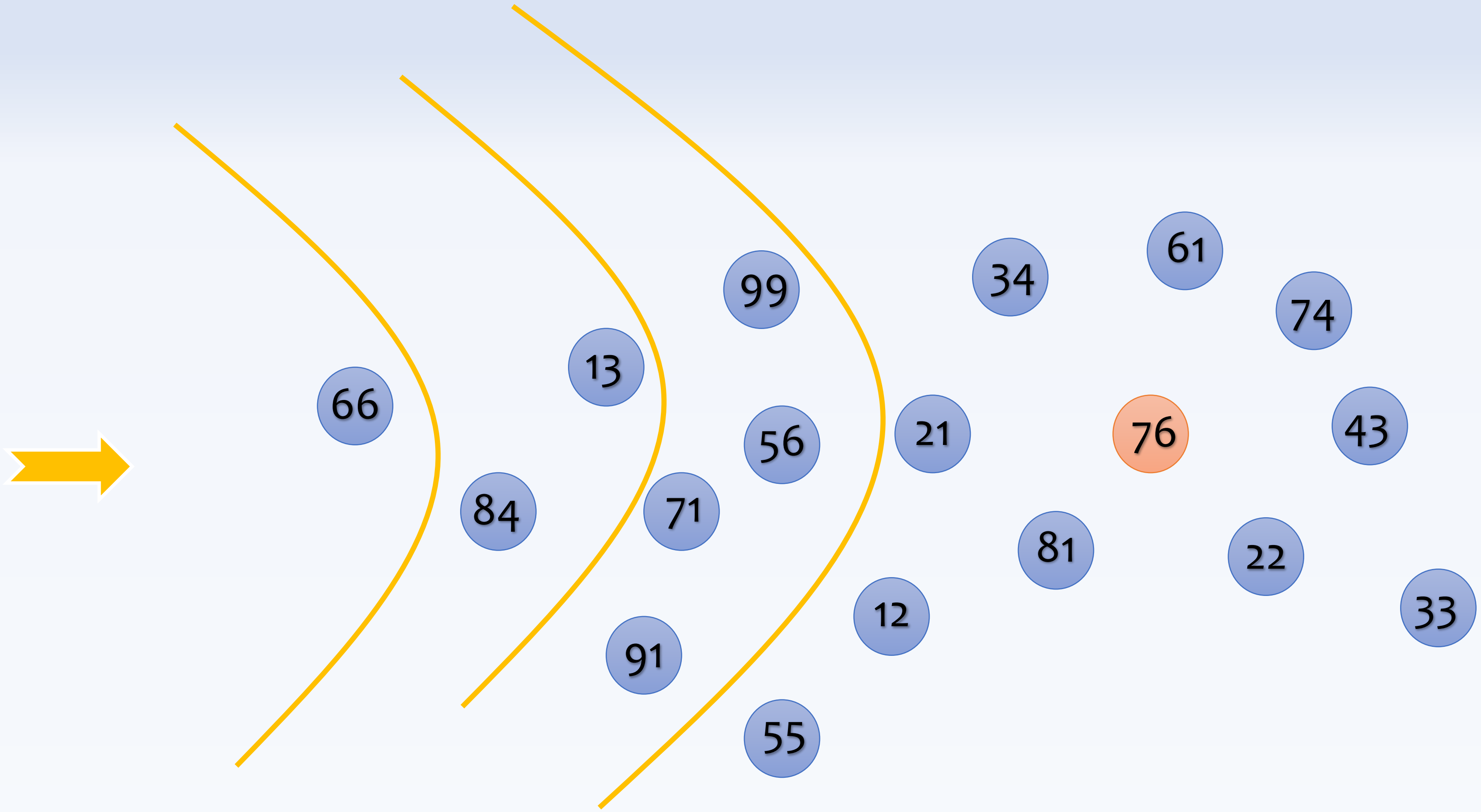

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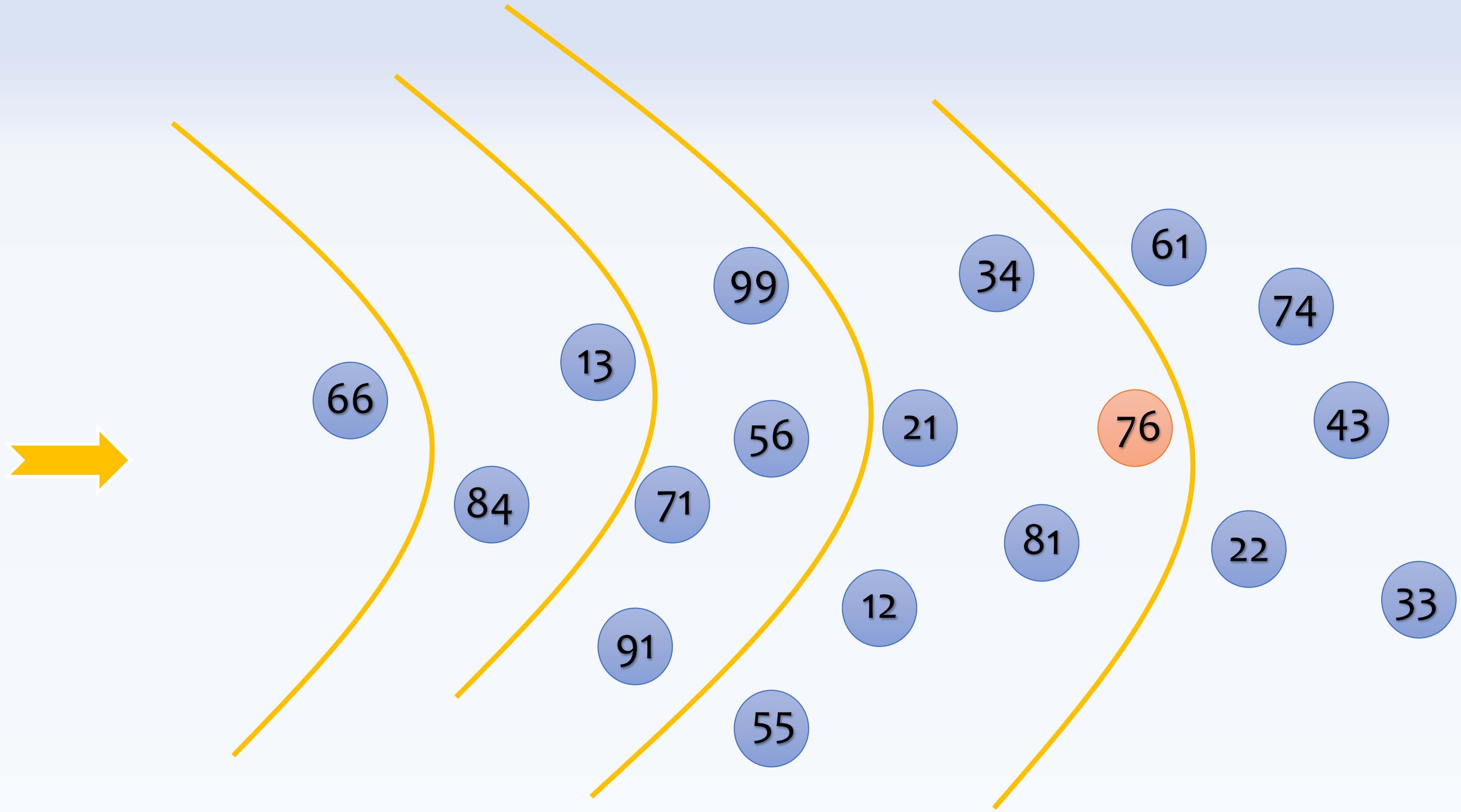

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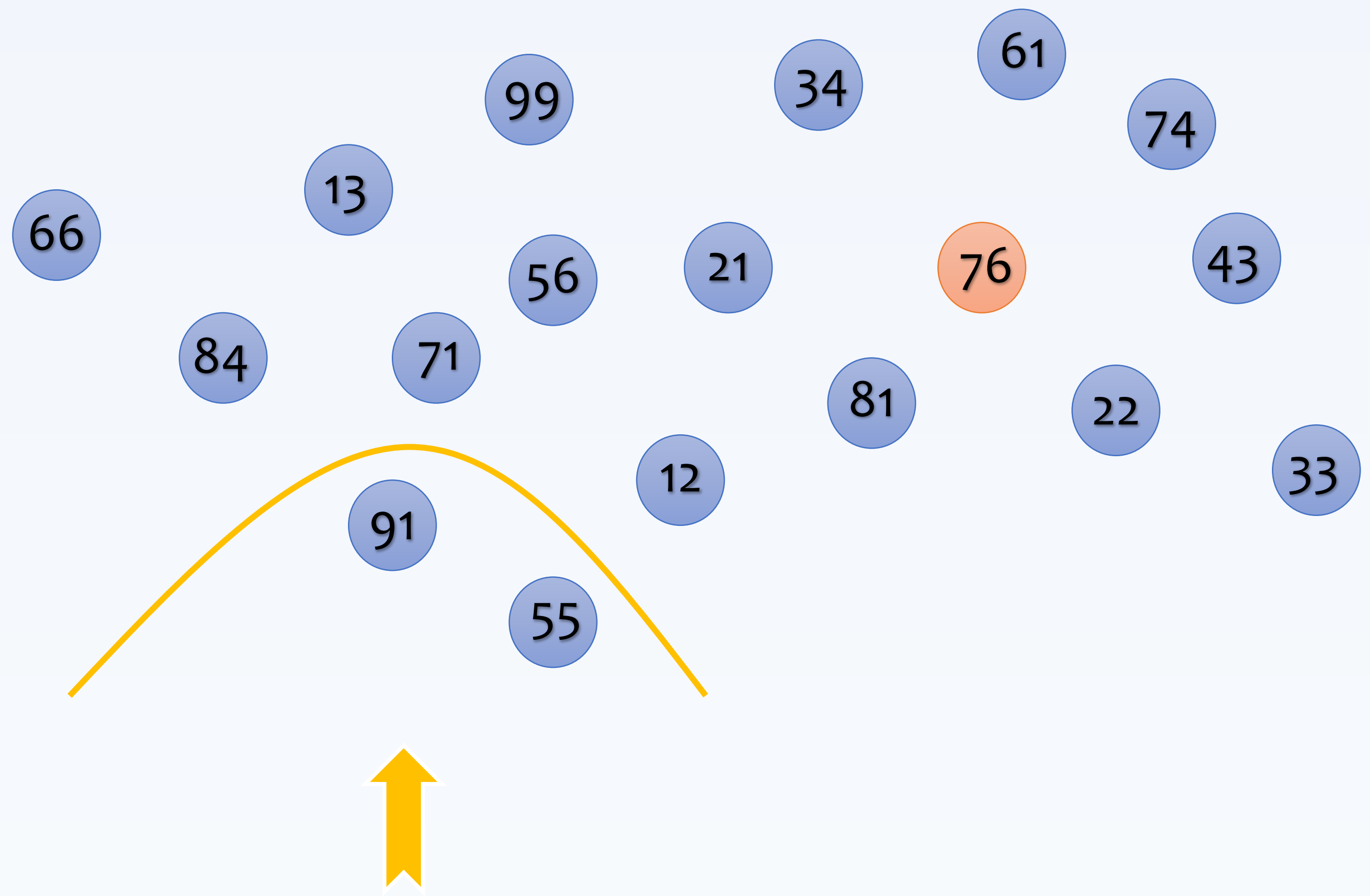

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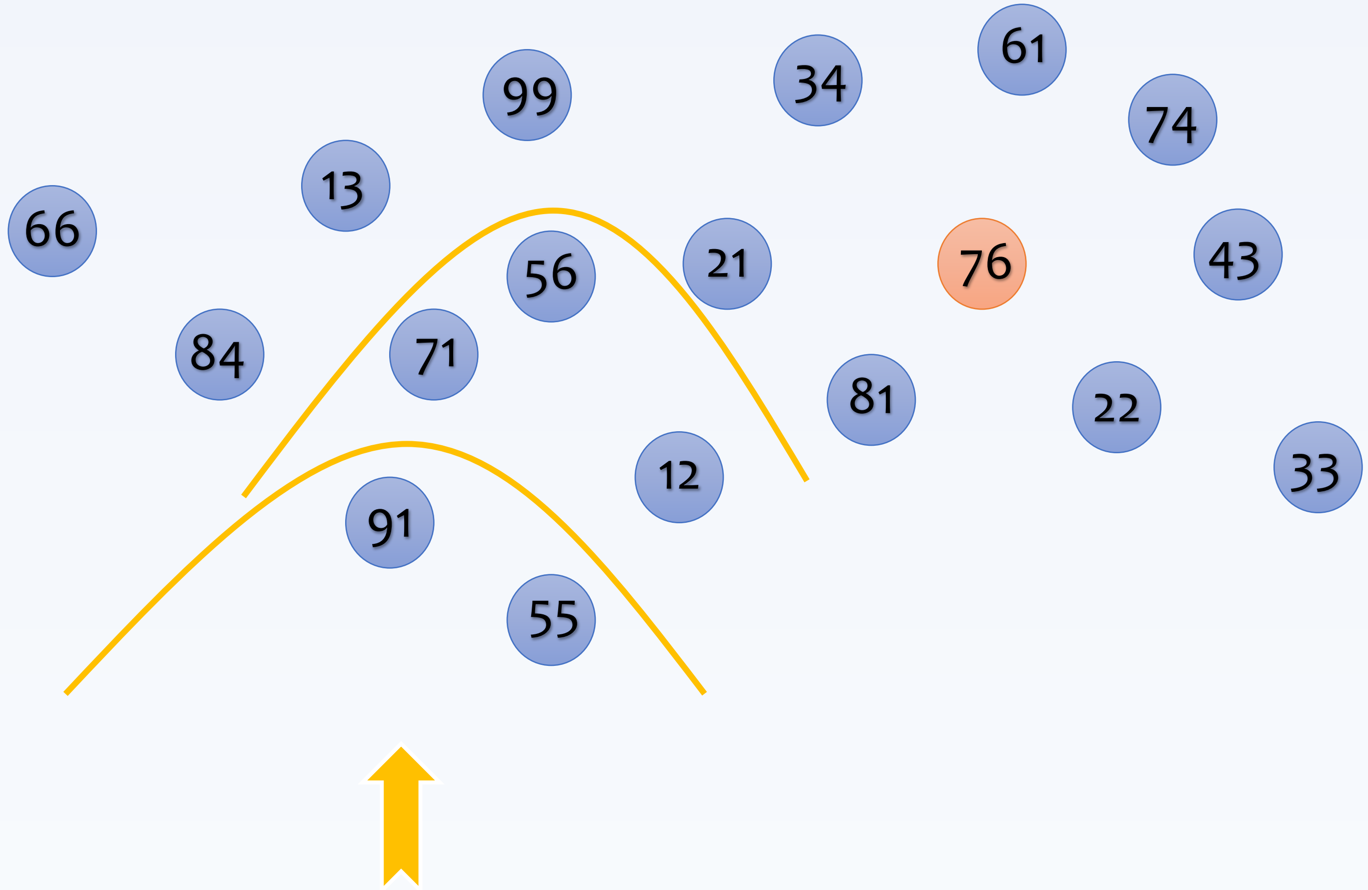

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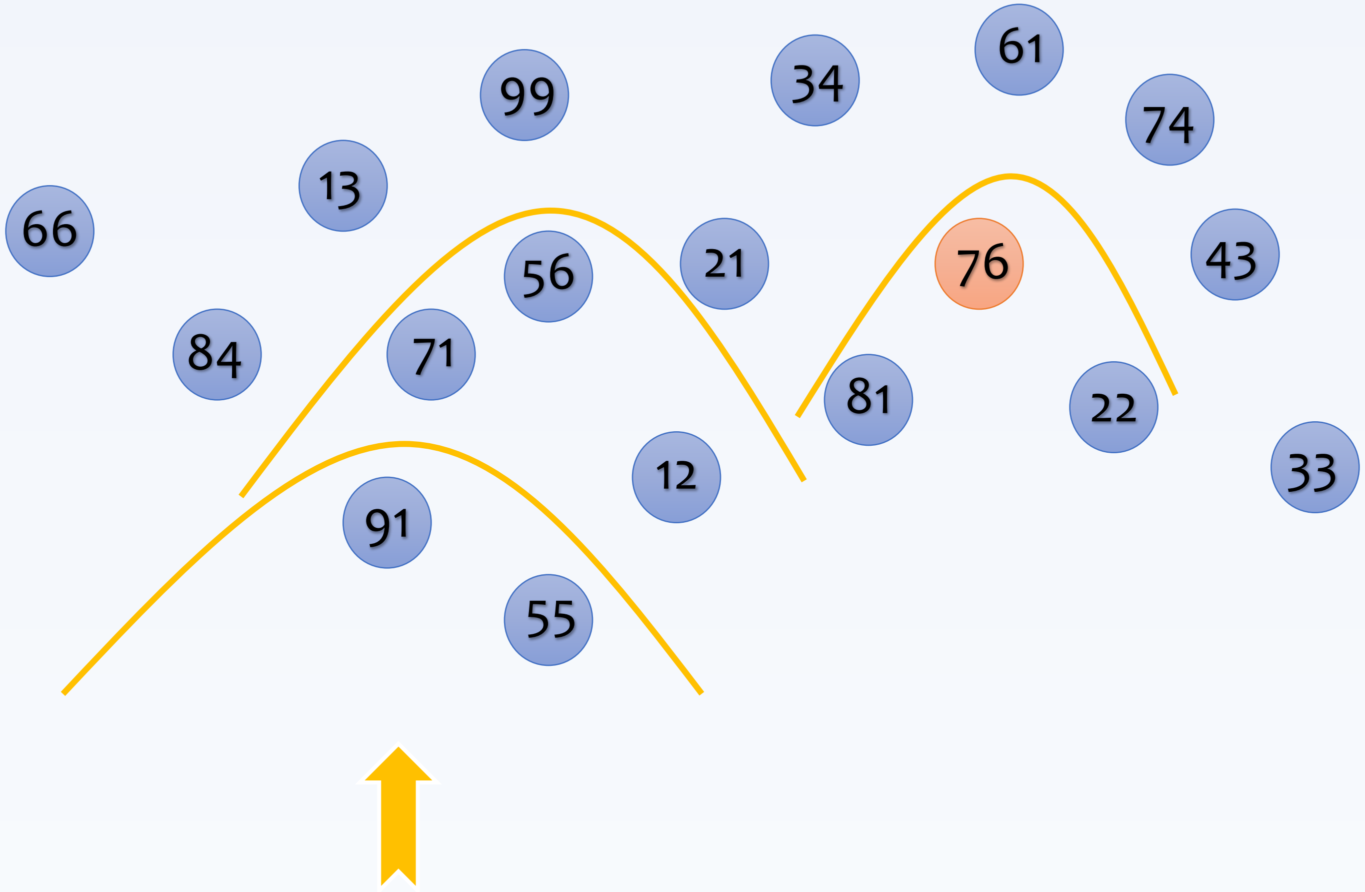

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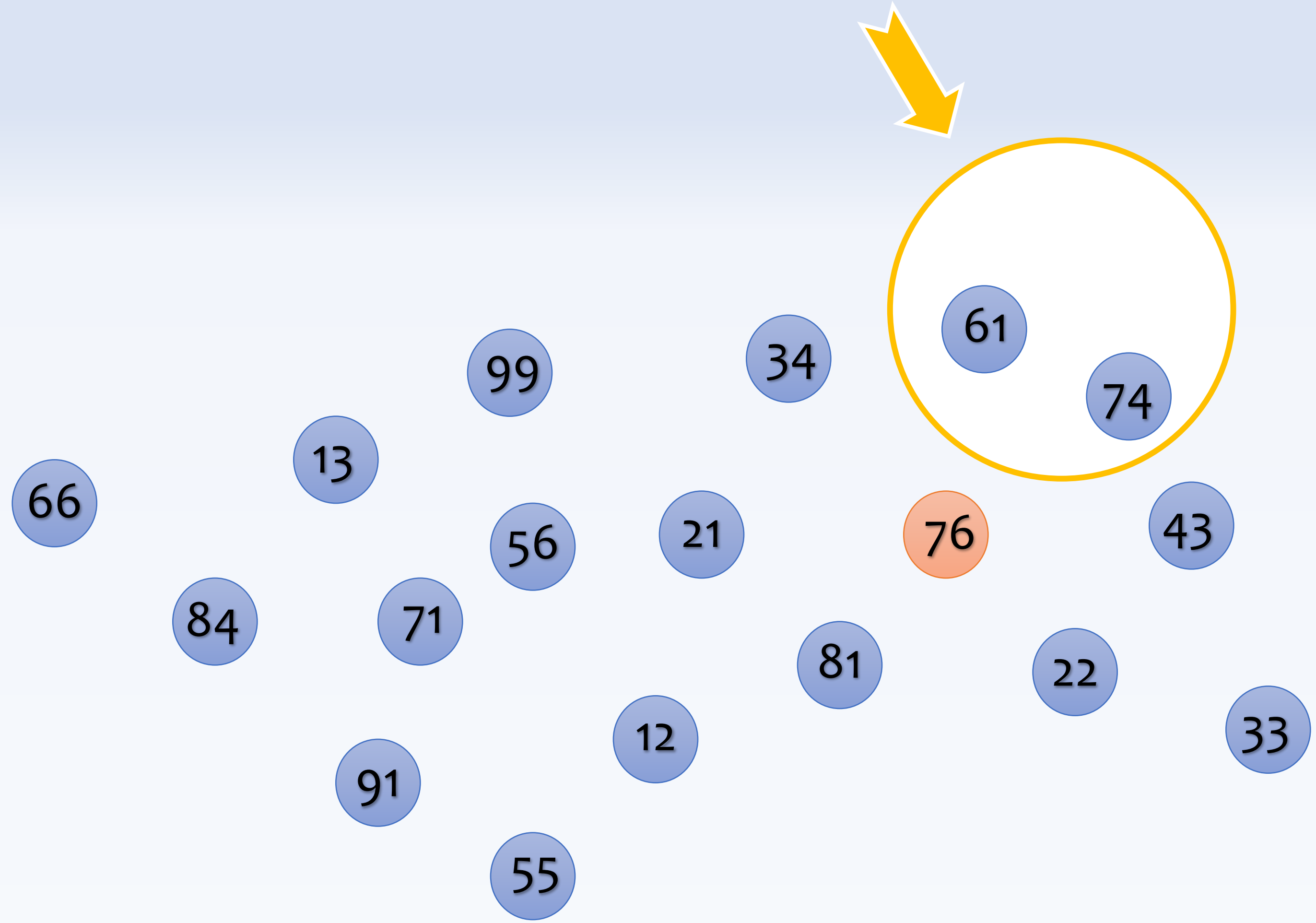
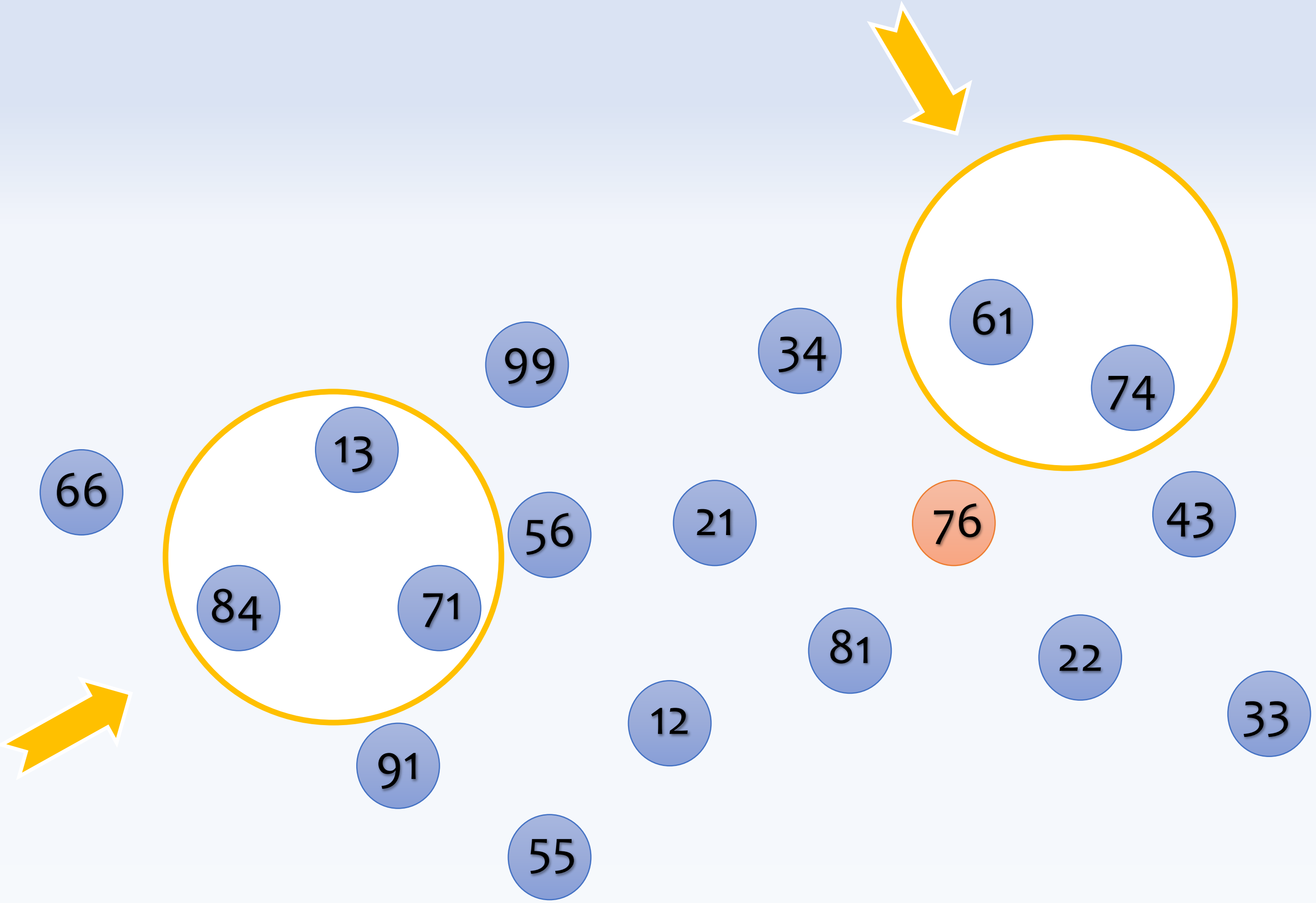
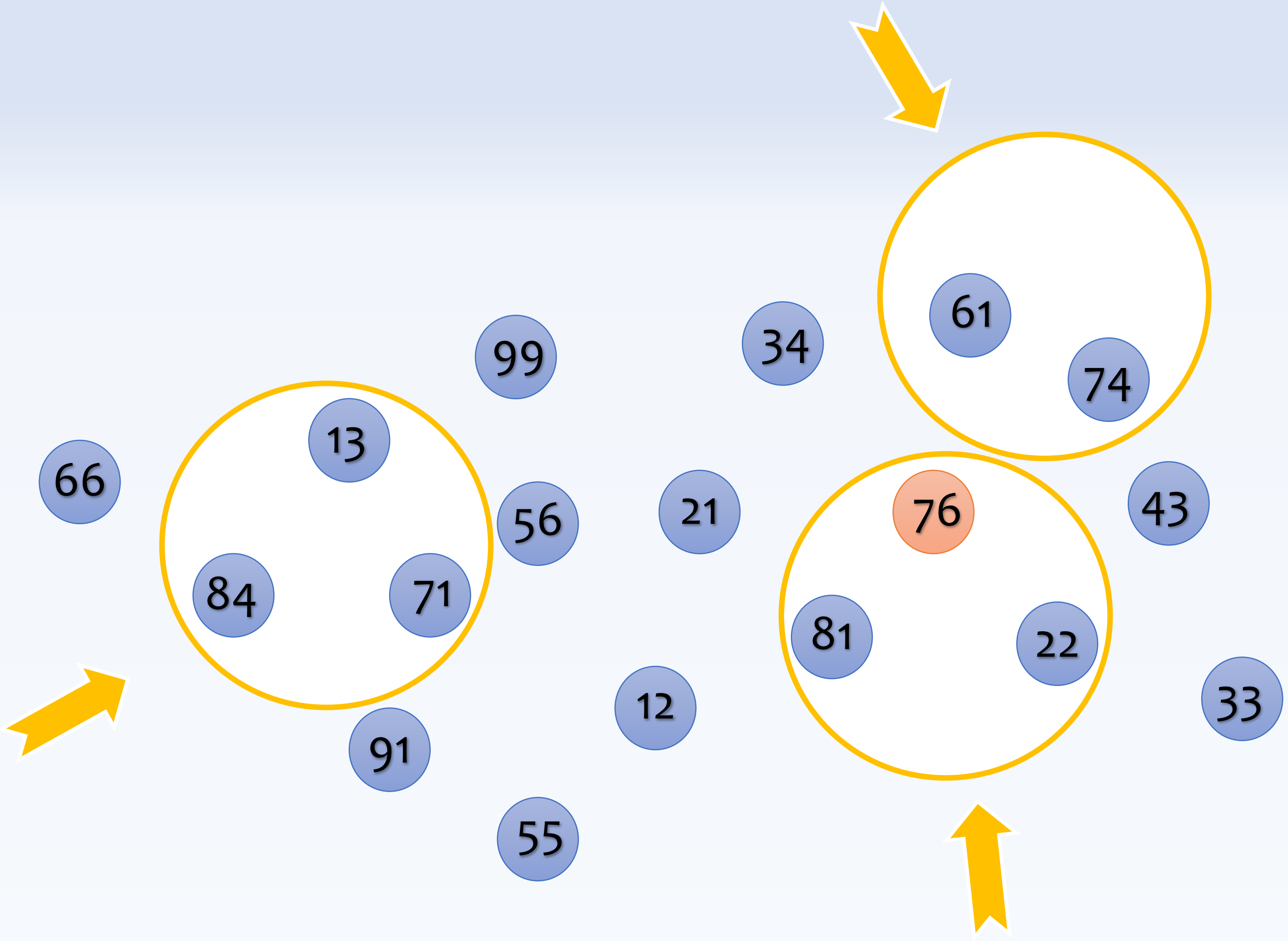


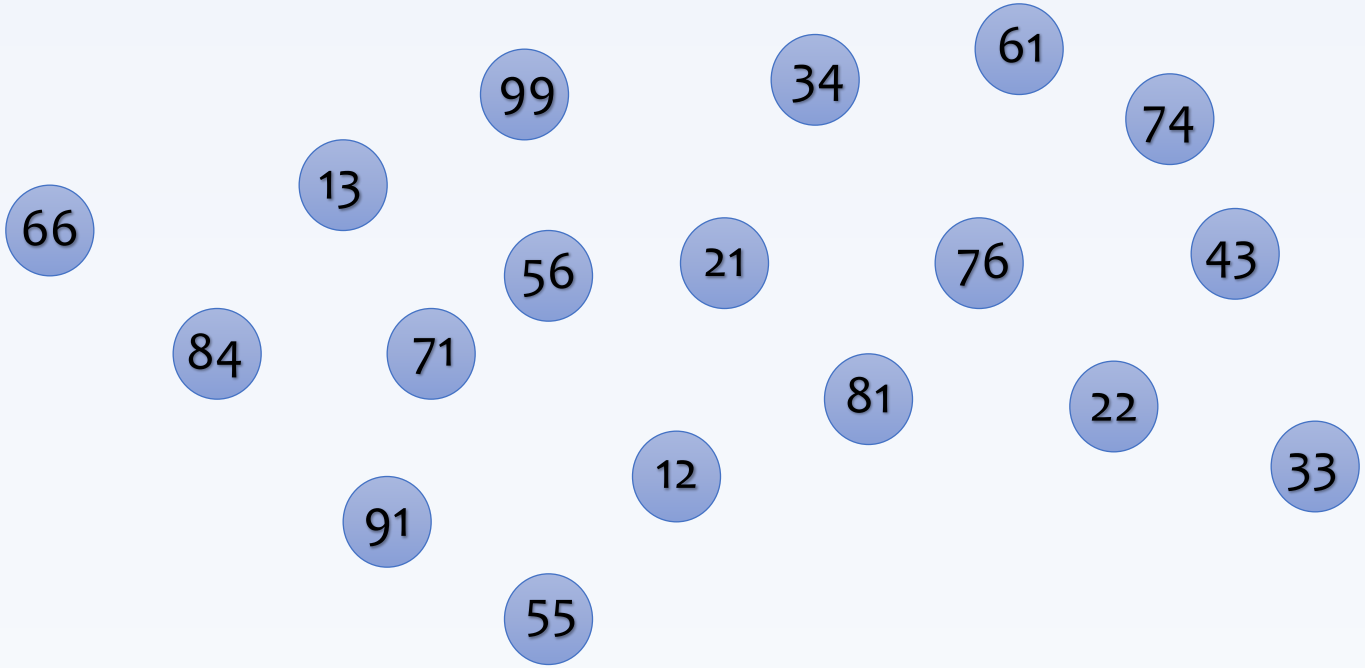
Searching for 76



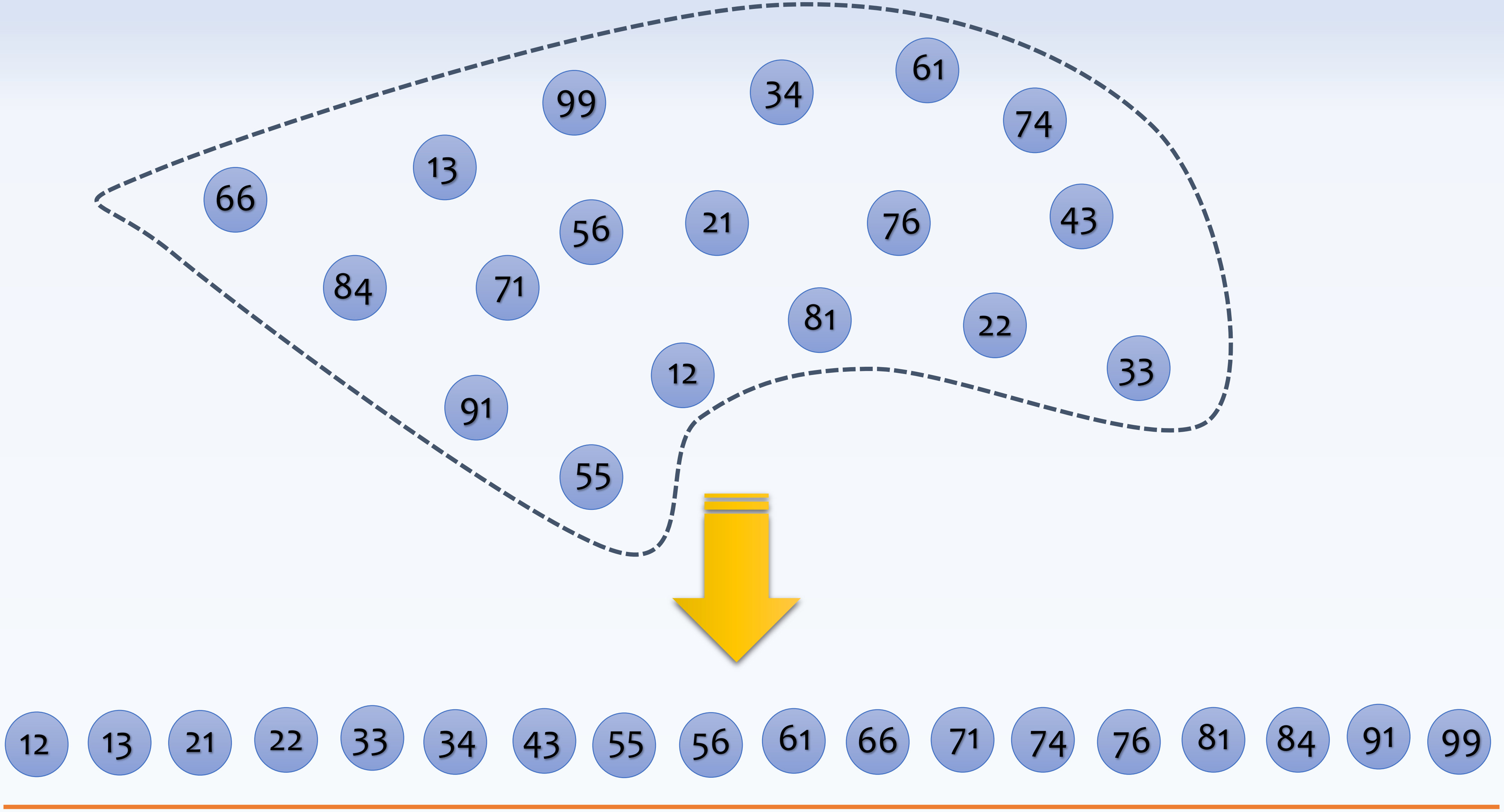
Searching for 76



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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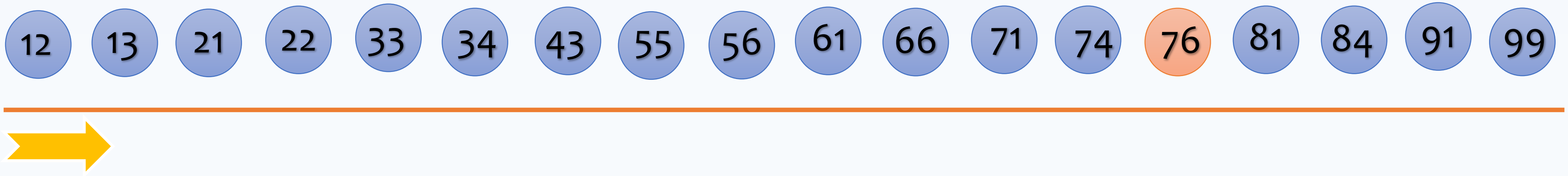
Searching for 76



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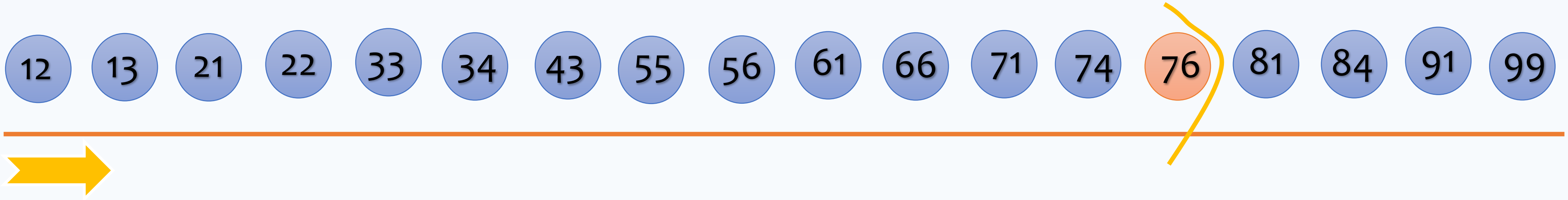
Searching for 76



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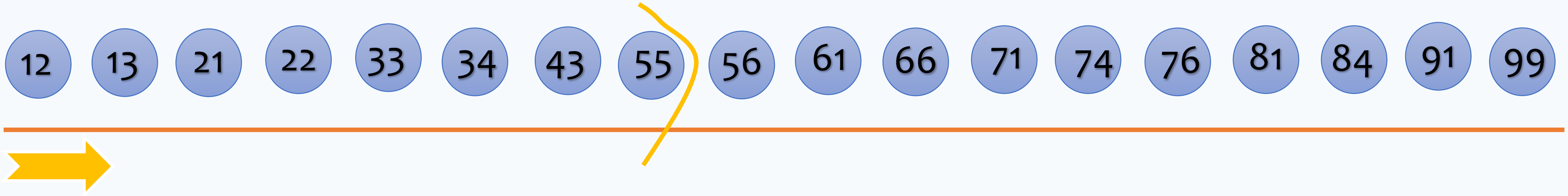
Searching for 44?
(could we have an early termination?)



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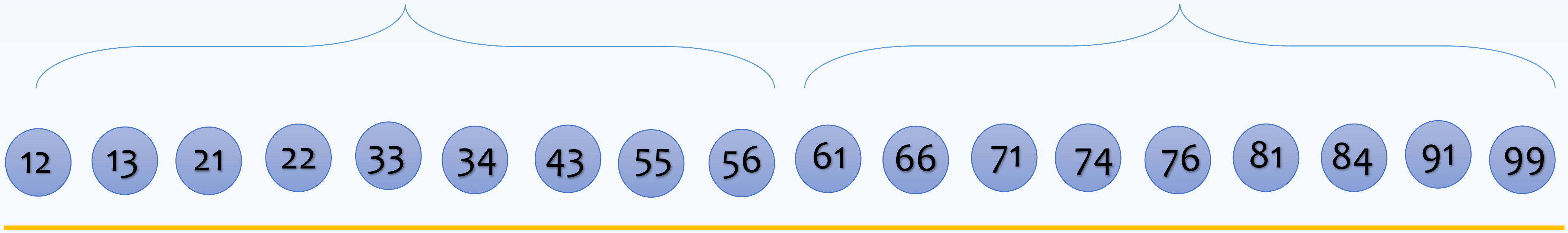
Could we impose a structure to further improve the search?



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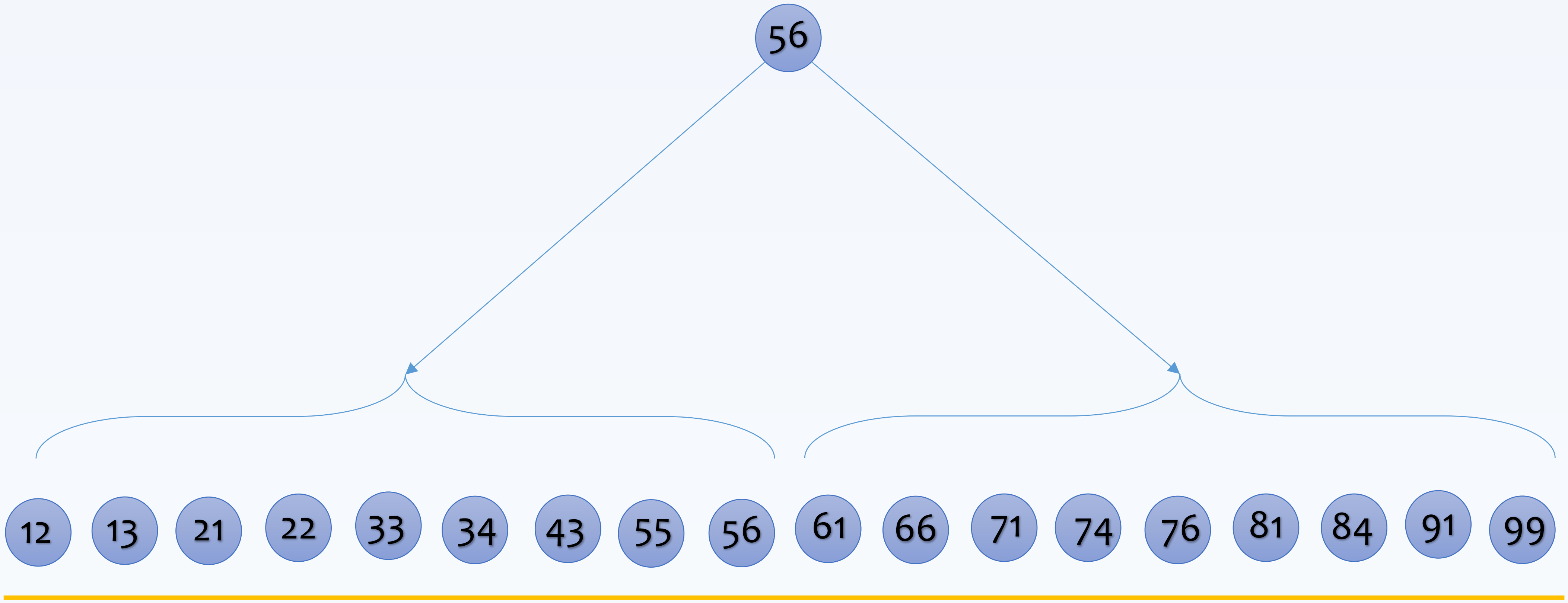
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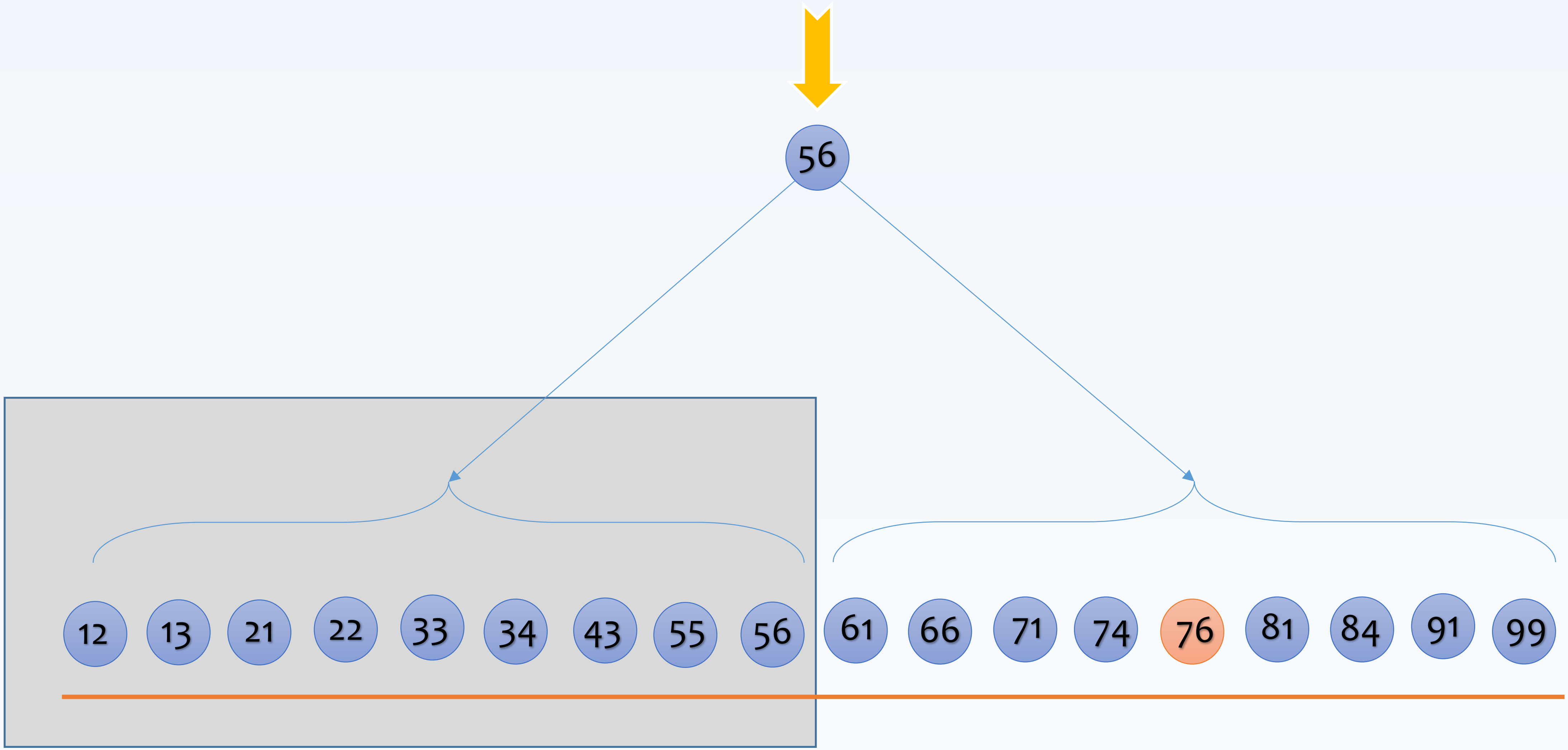
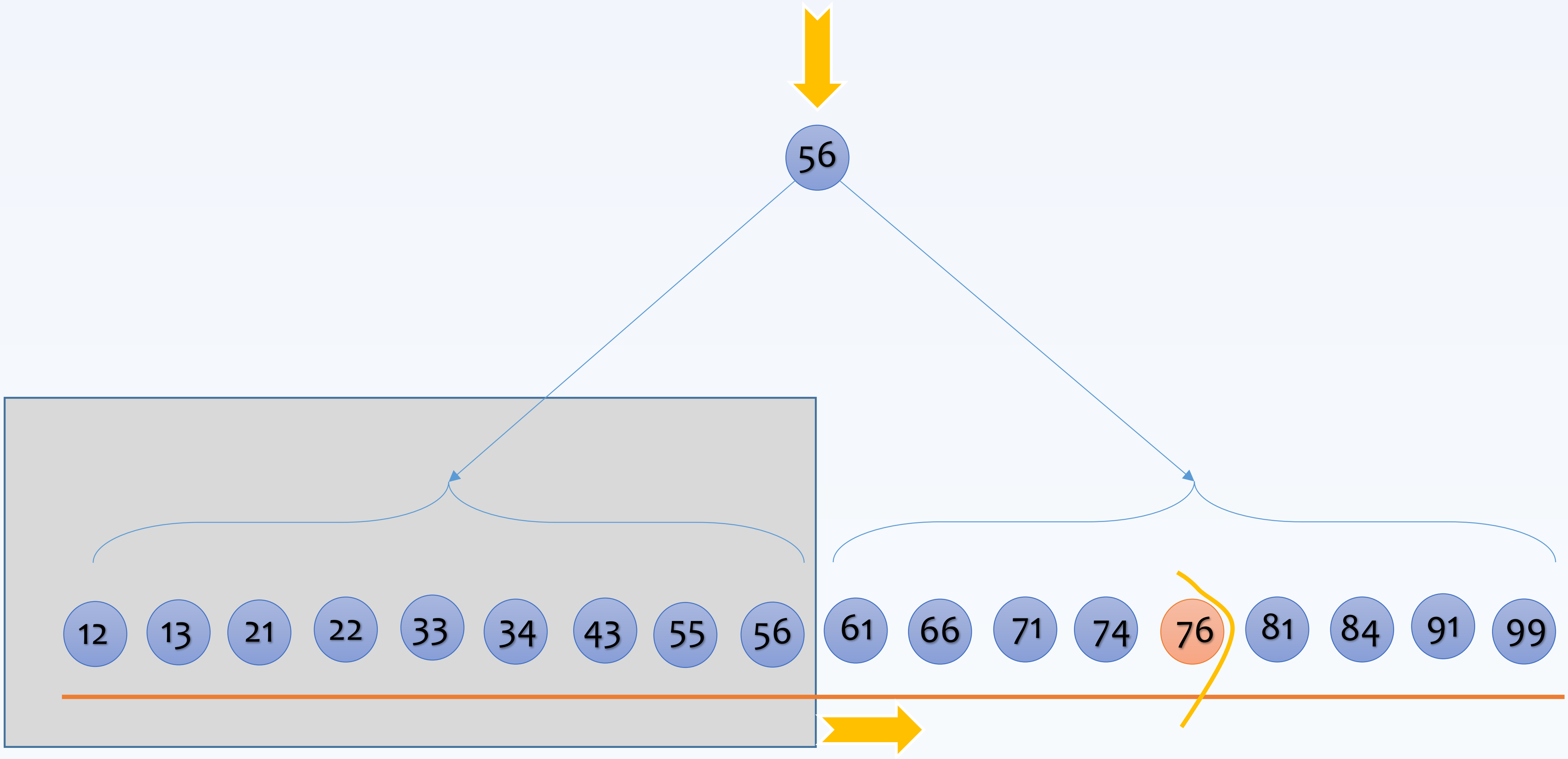
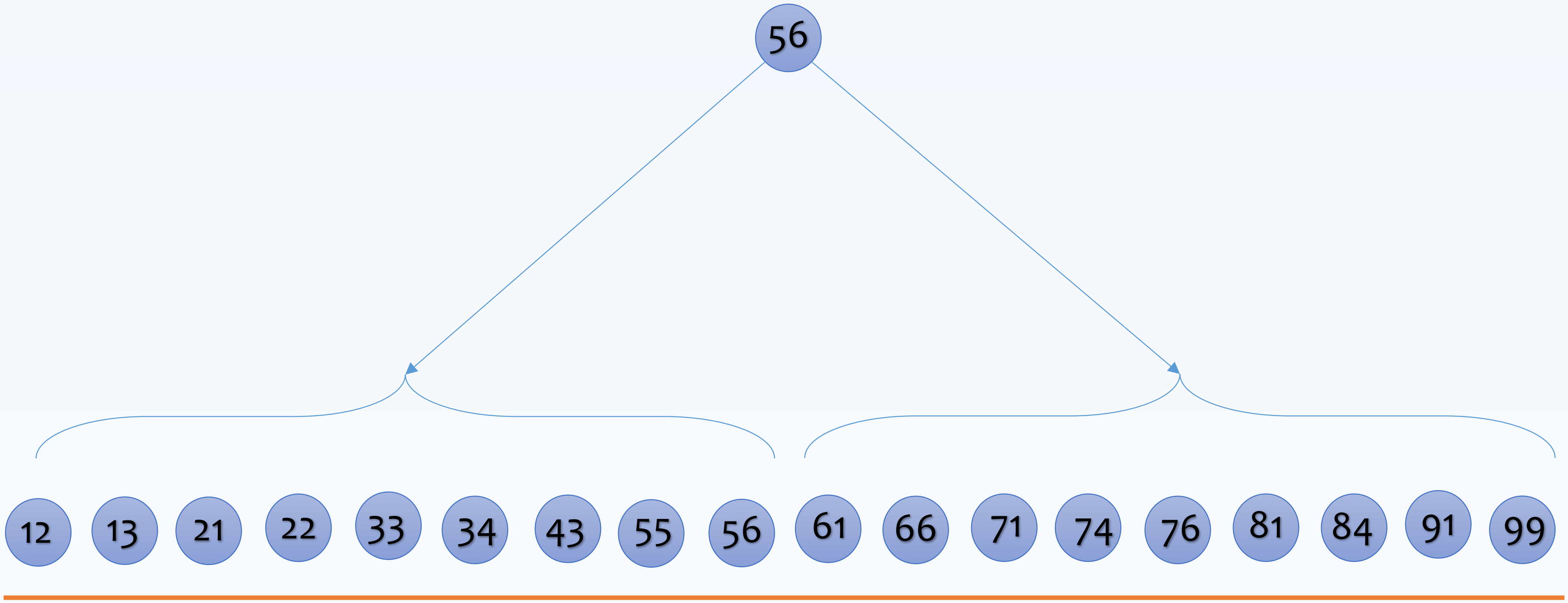
Searching for 76



Searching for 76

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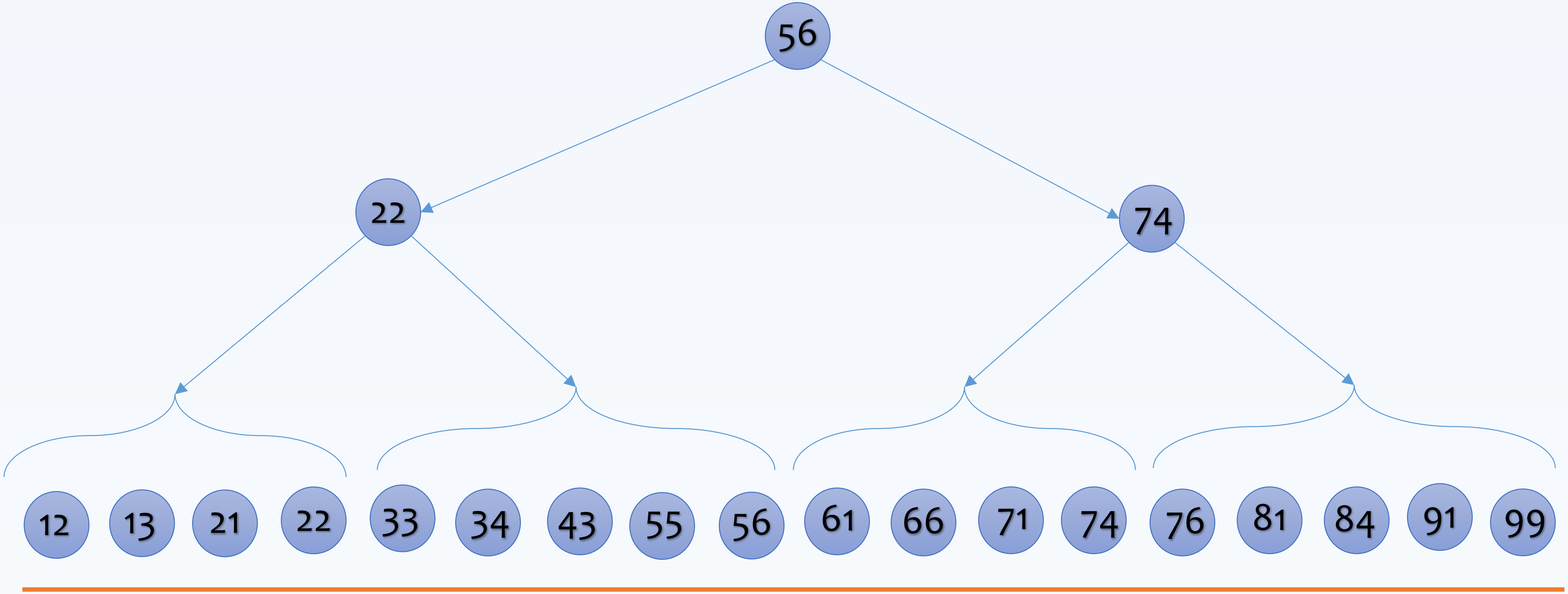
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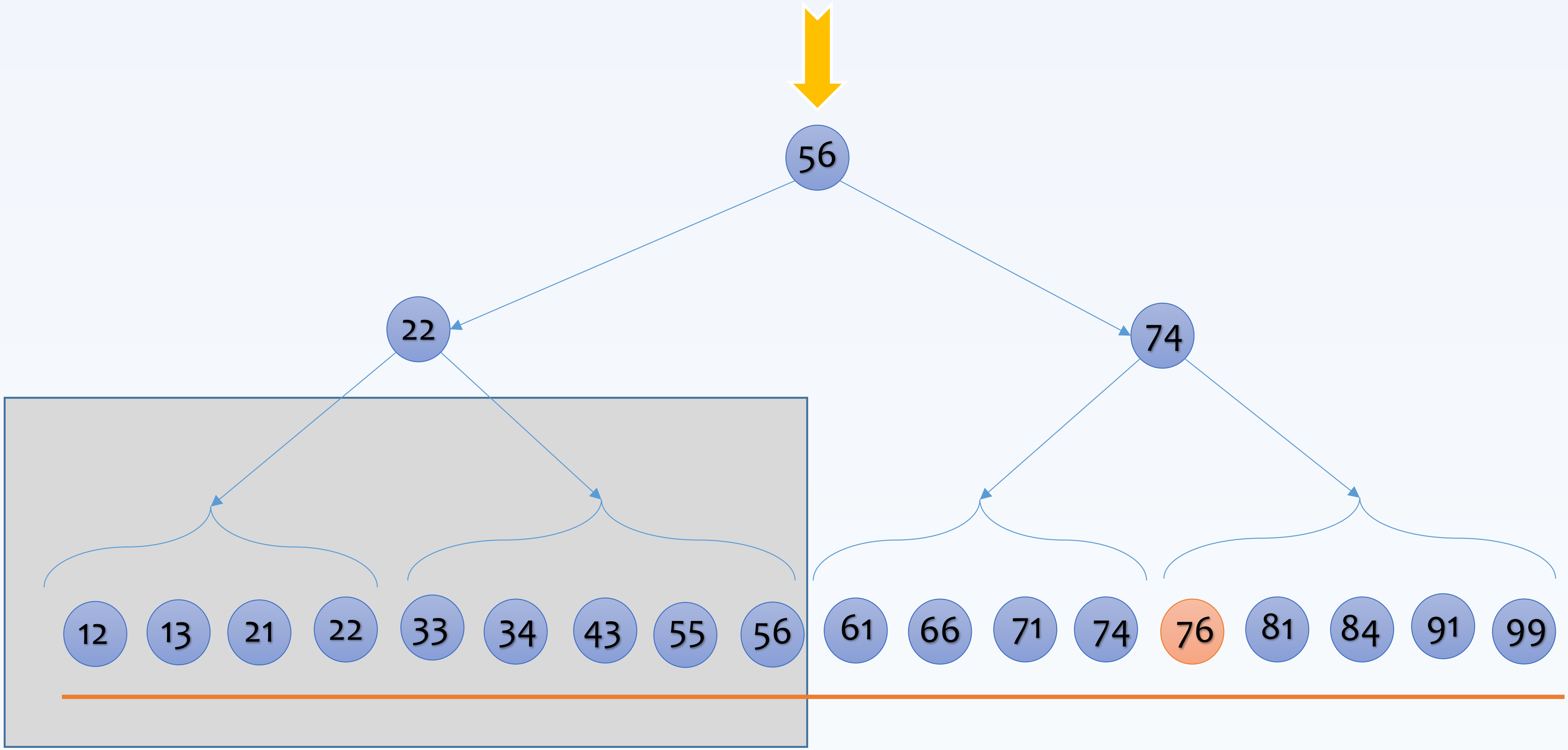
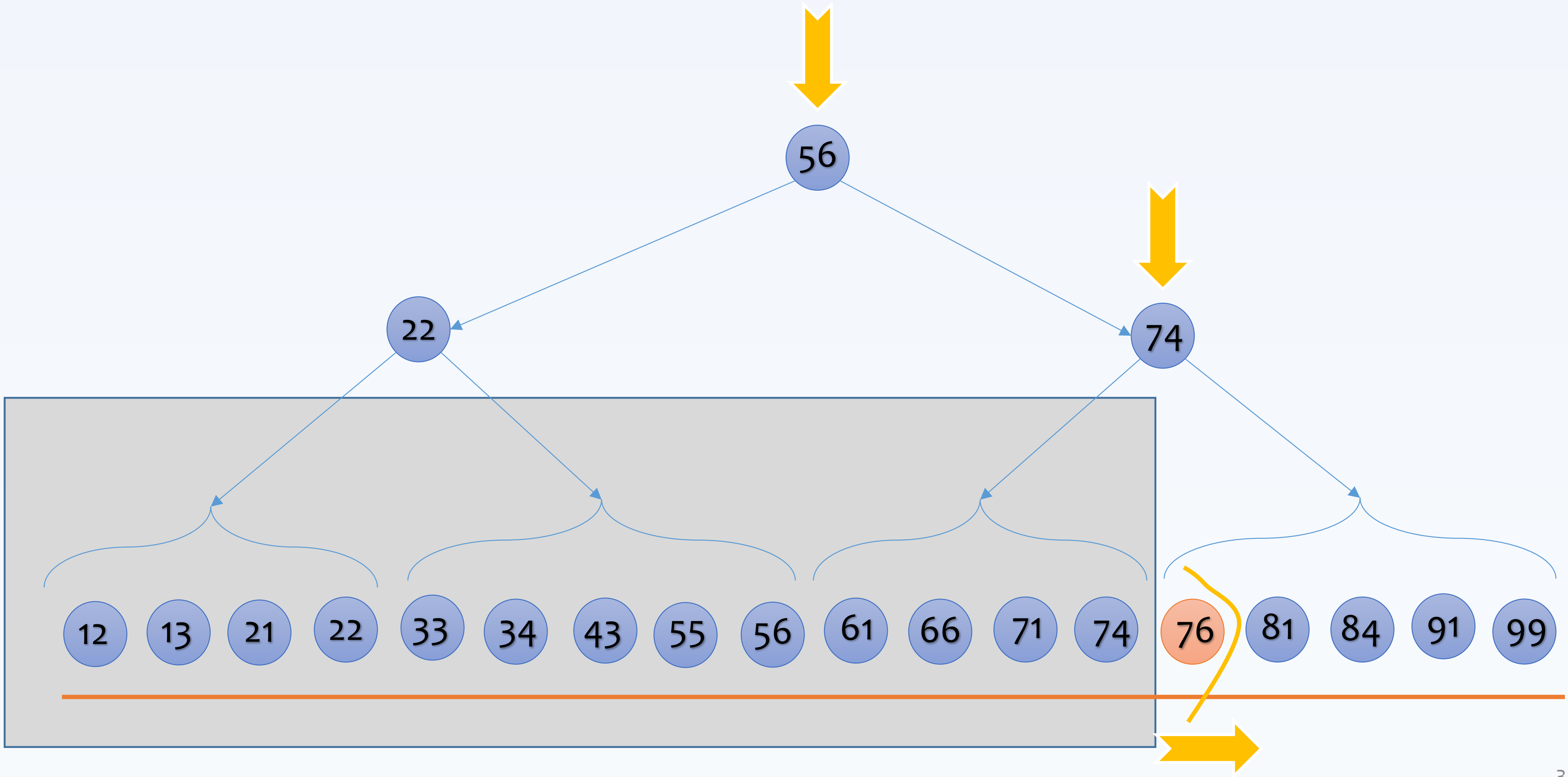
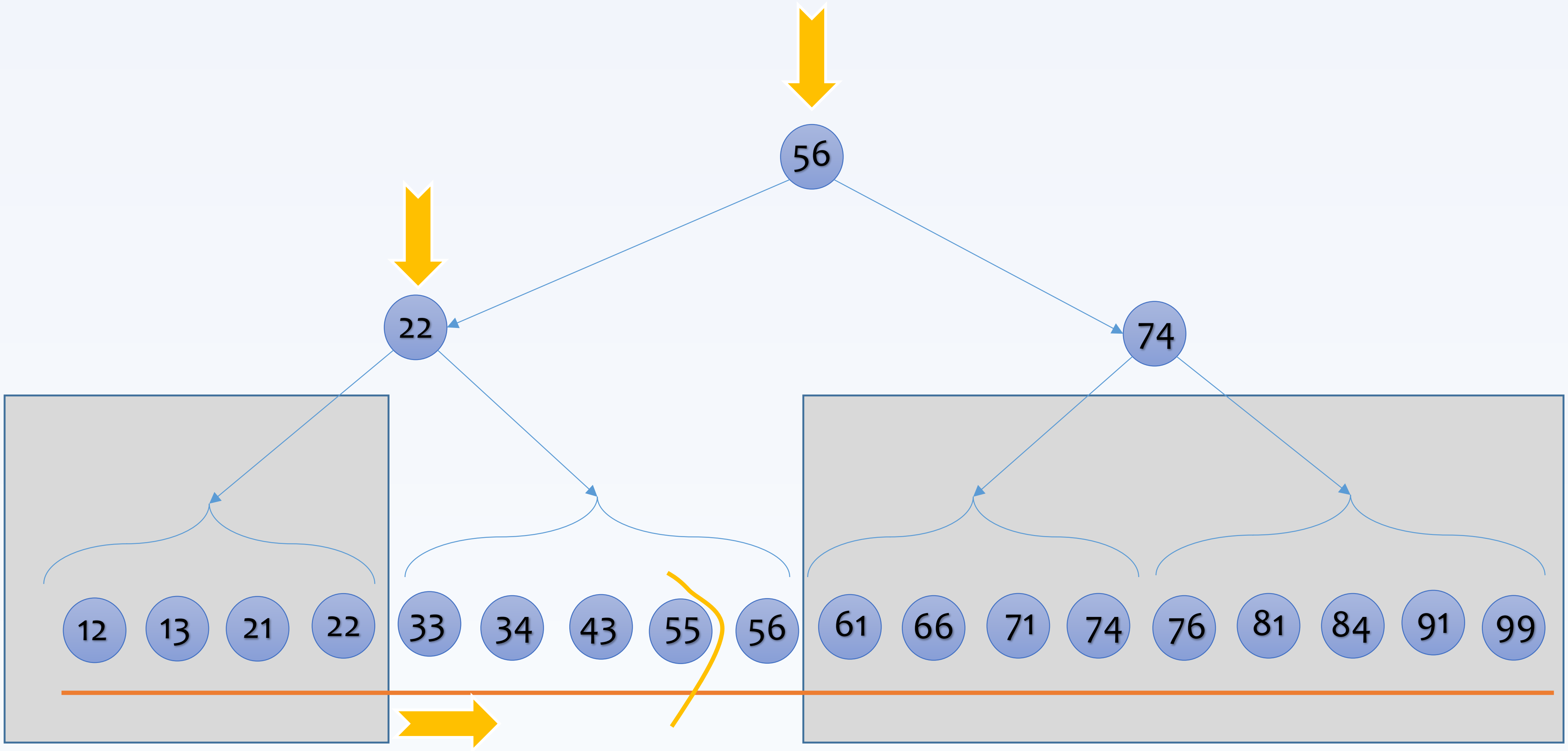
Searching for 76



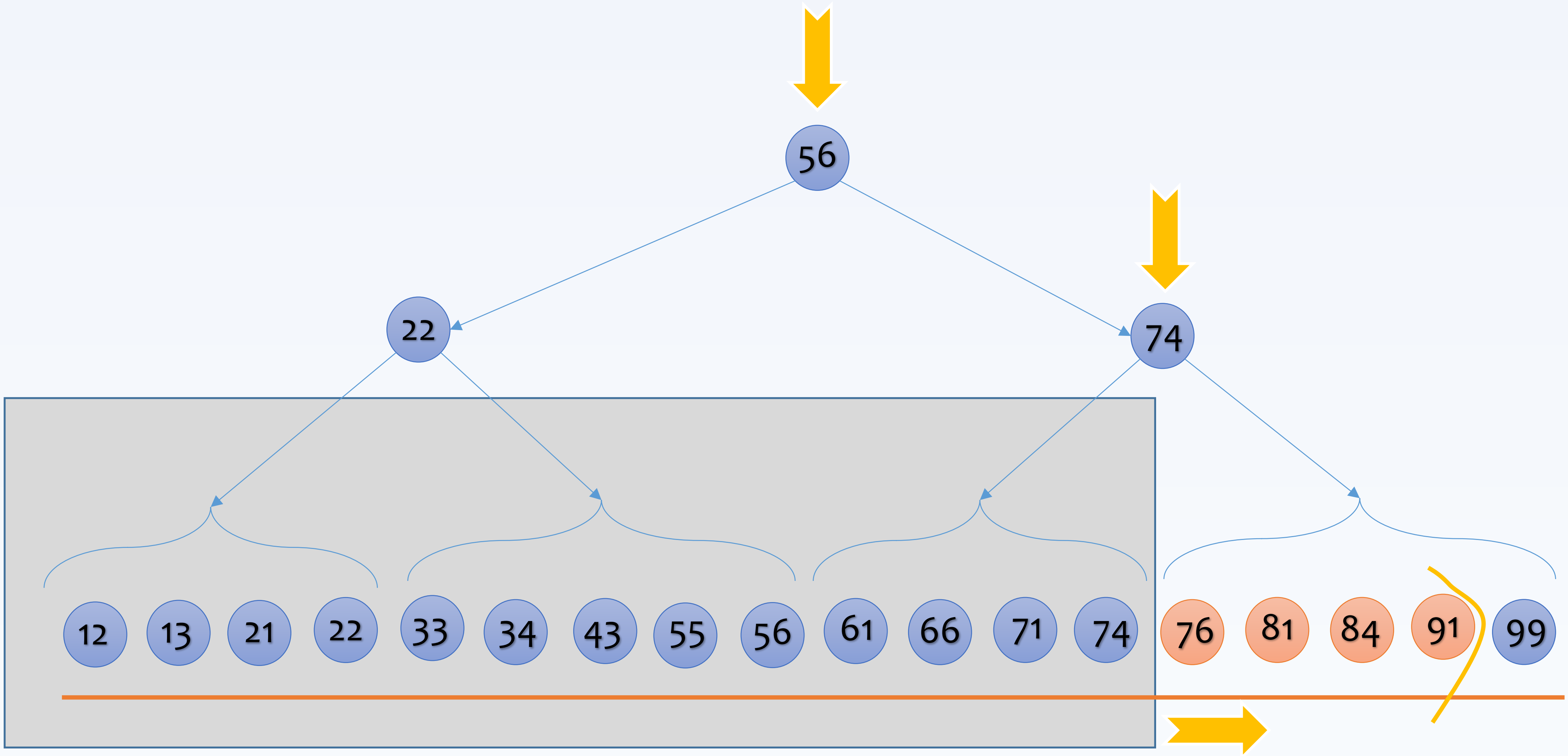
Searching for 76



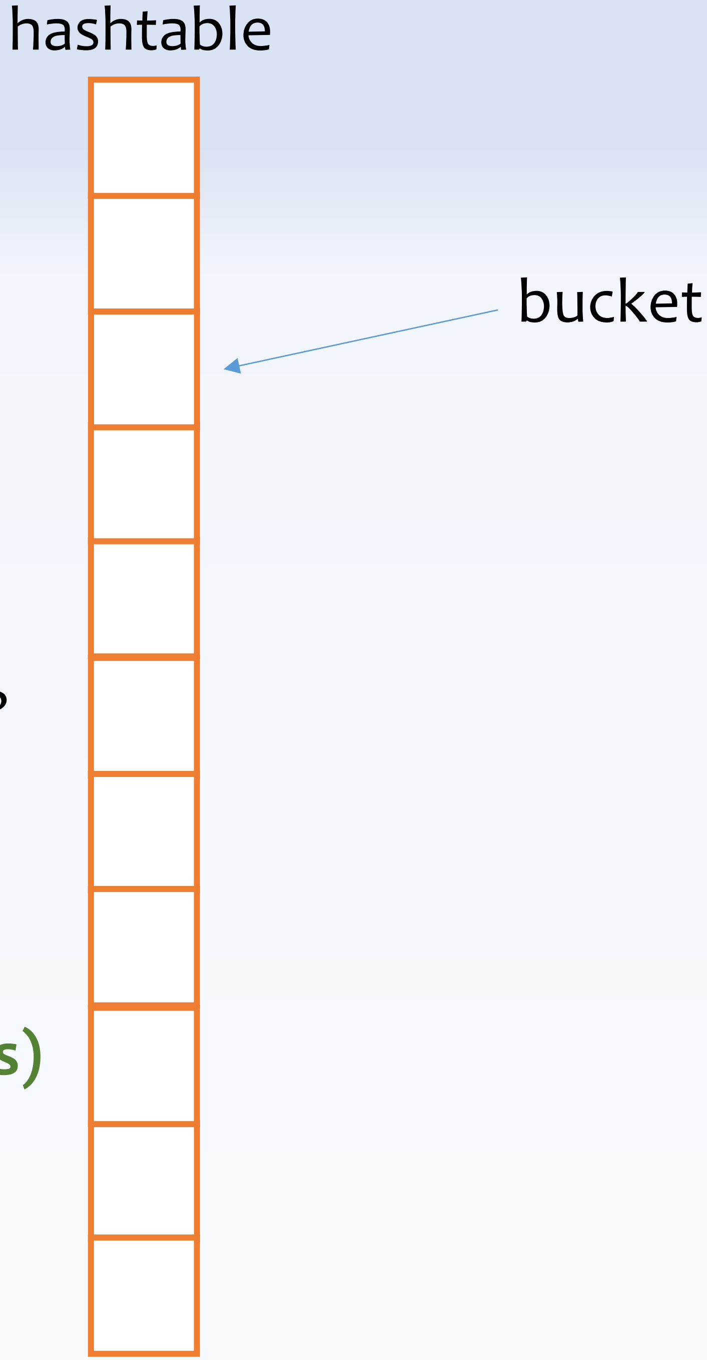
Searching for 44?
(could we have an early termination?)



Searching for 76-91



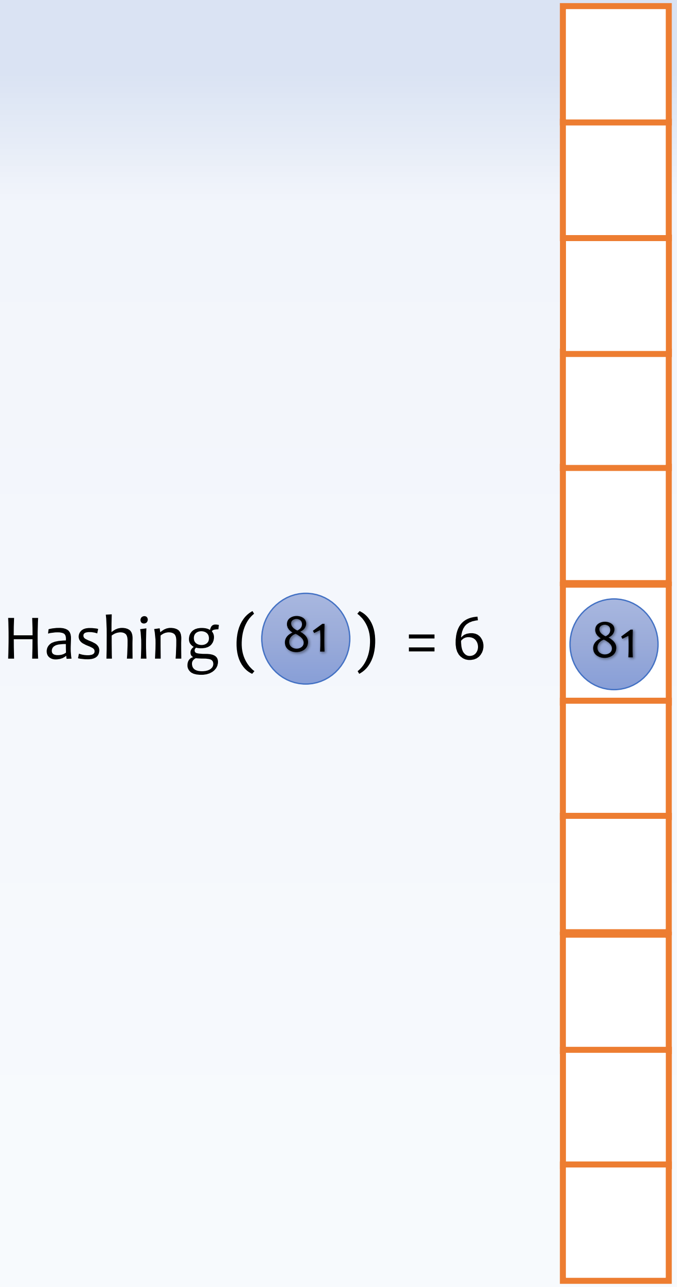
Could we spread the data cleverly to improve the search?



Hashing (●) = ?

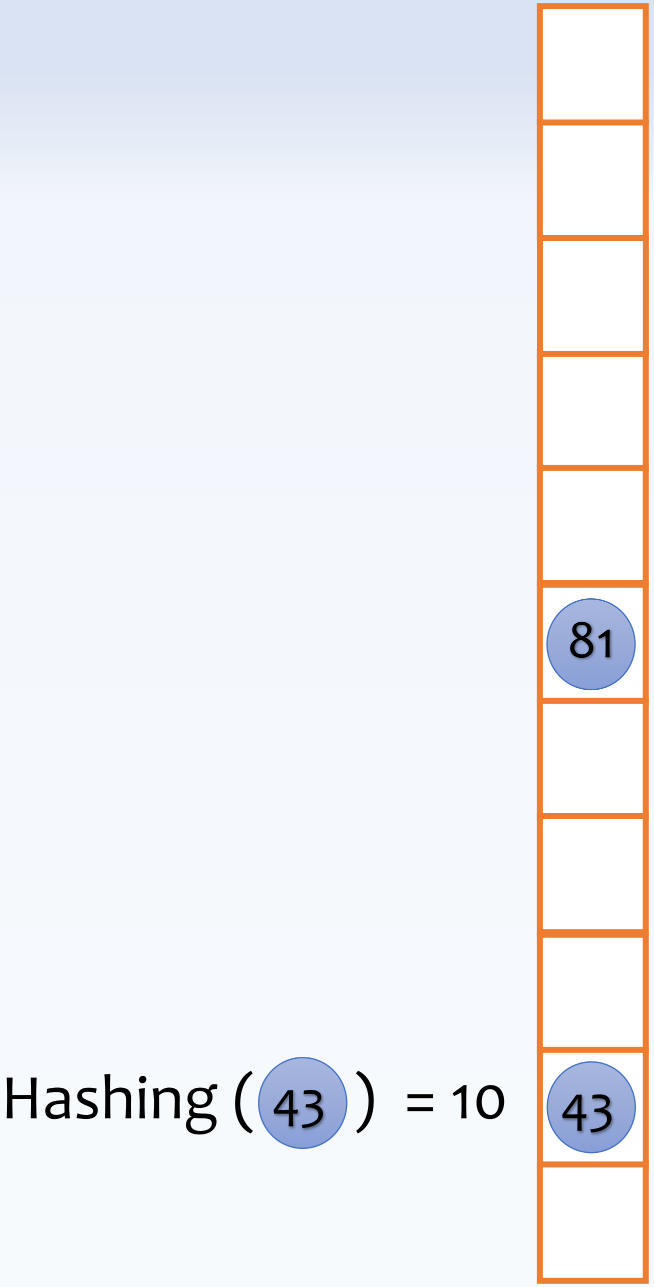
(returns a value between 1 to n, where n is the number of buckets)

Inserting 81



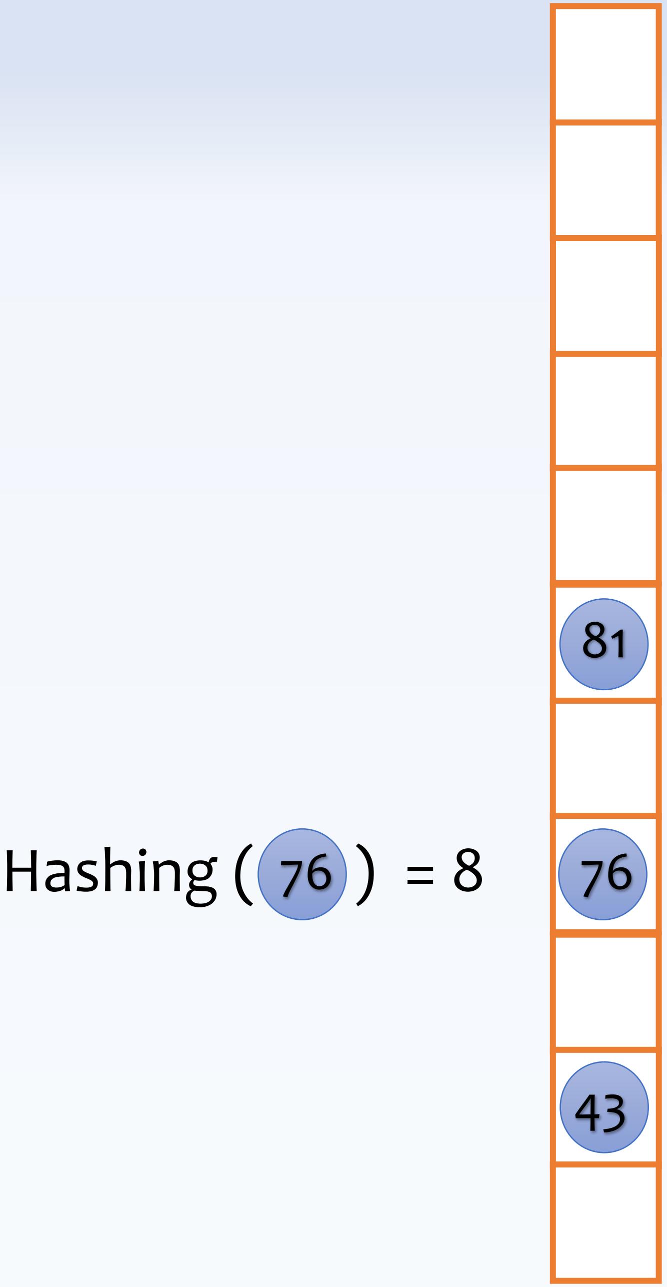
Hashing (81) = 6

Inserting 43

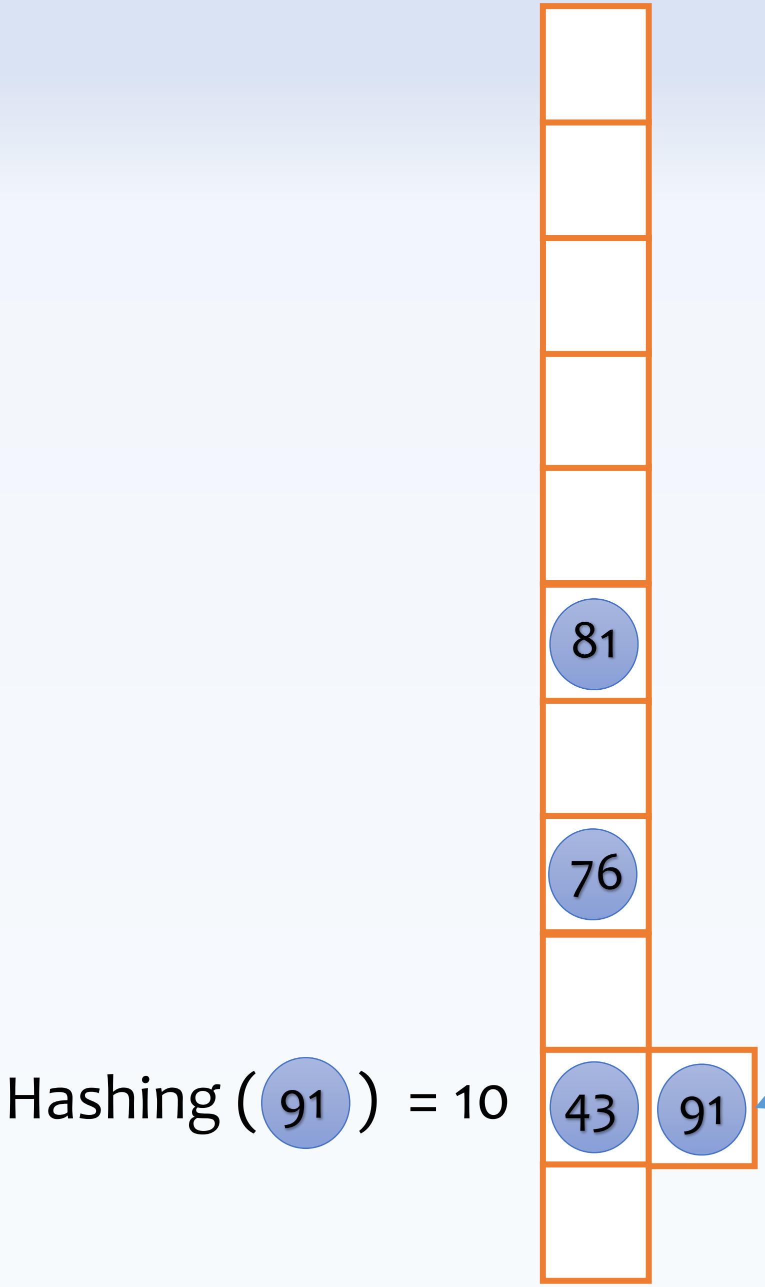


Hashing (43) = 10

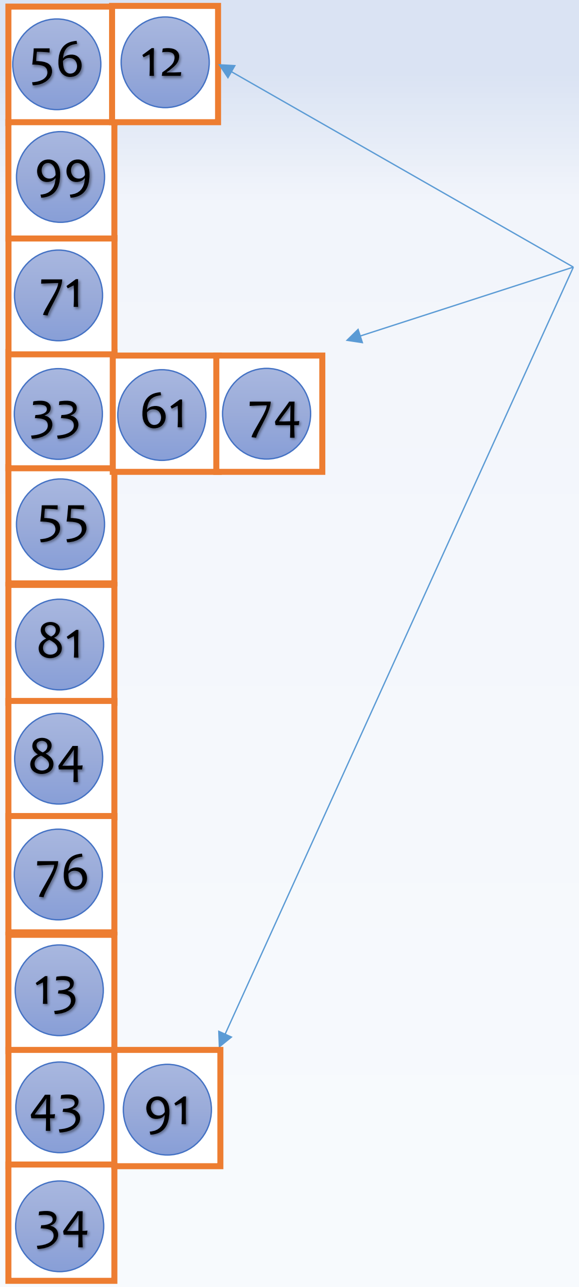
Inserting 76



Inserting 91



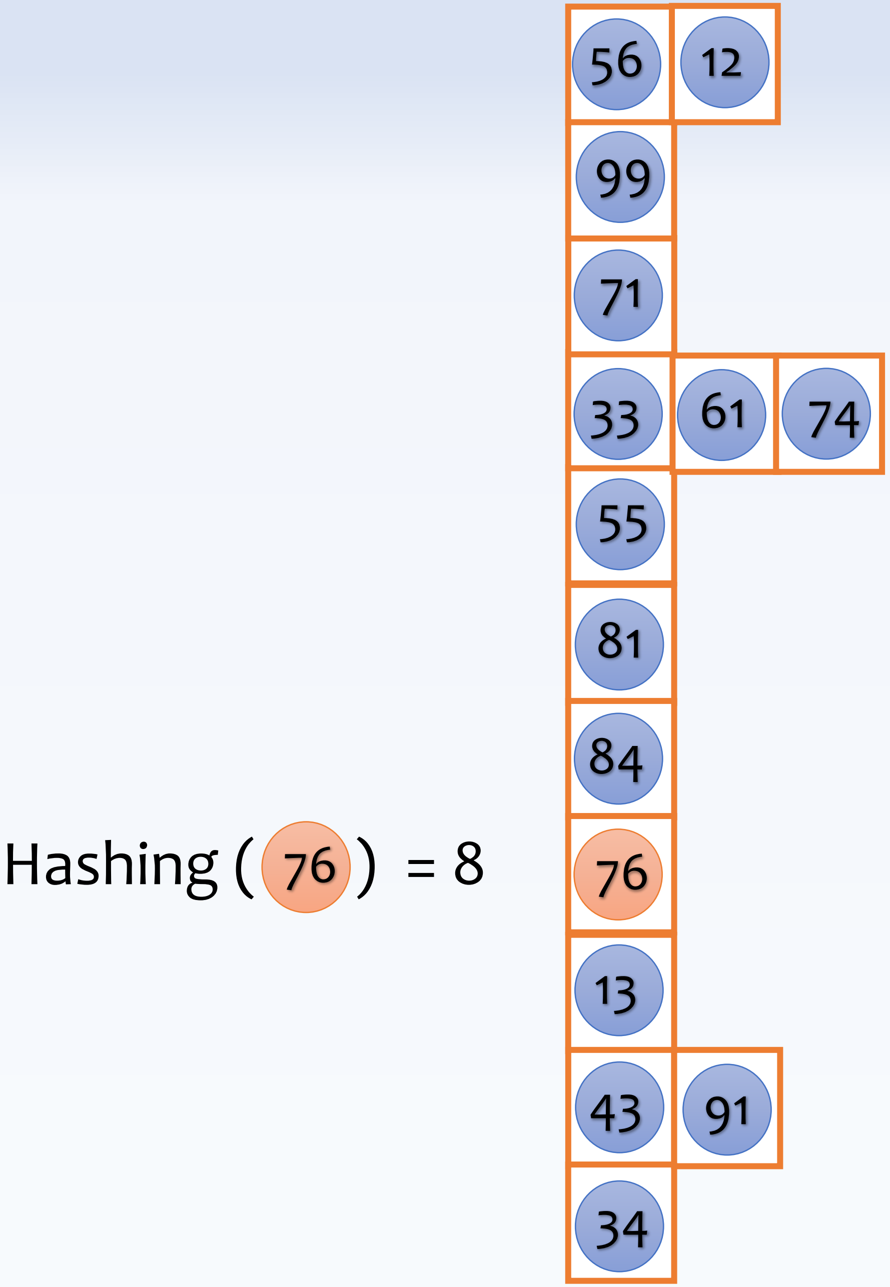
collisions
(when multiple values
hash to the same bucket)

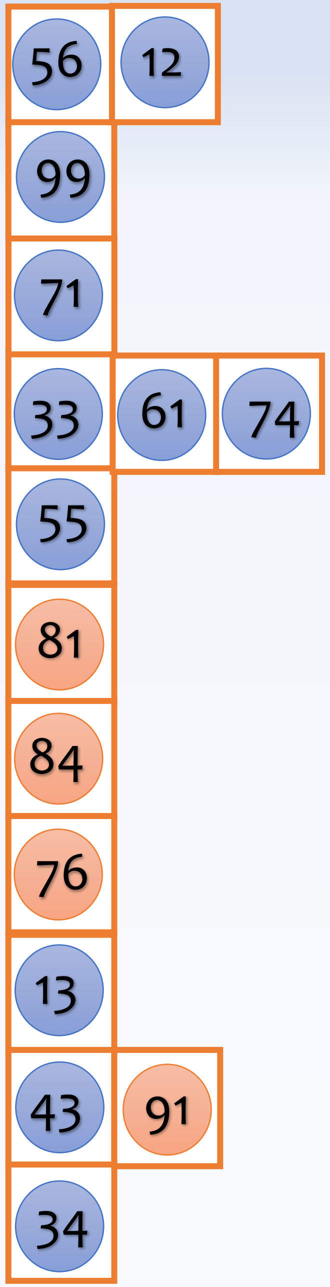


collisions
(when multiple values
hash to the same bucket)

Searching for 76

(now we can have a constant lookup cost)



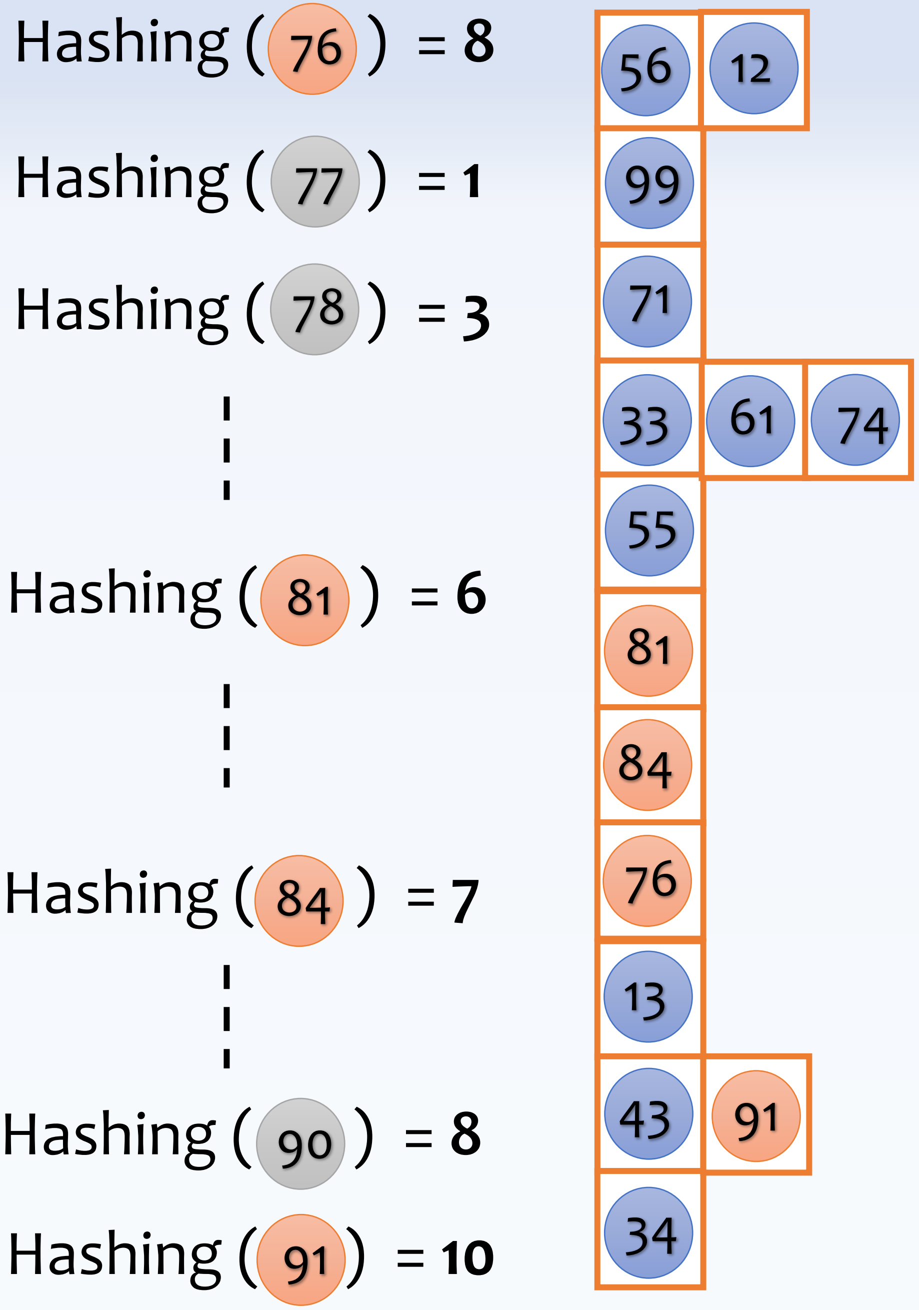


Searching for 76-91?

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

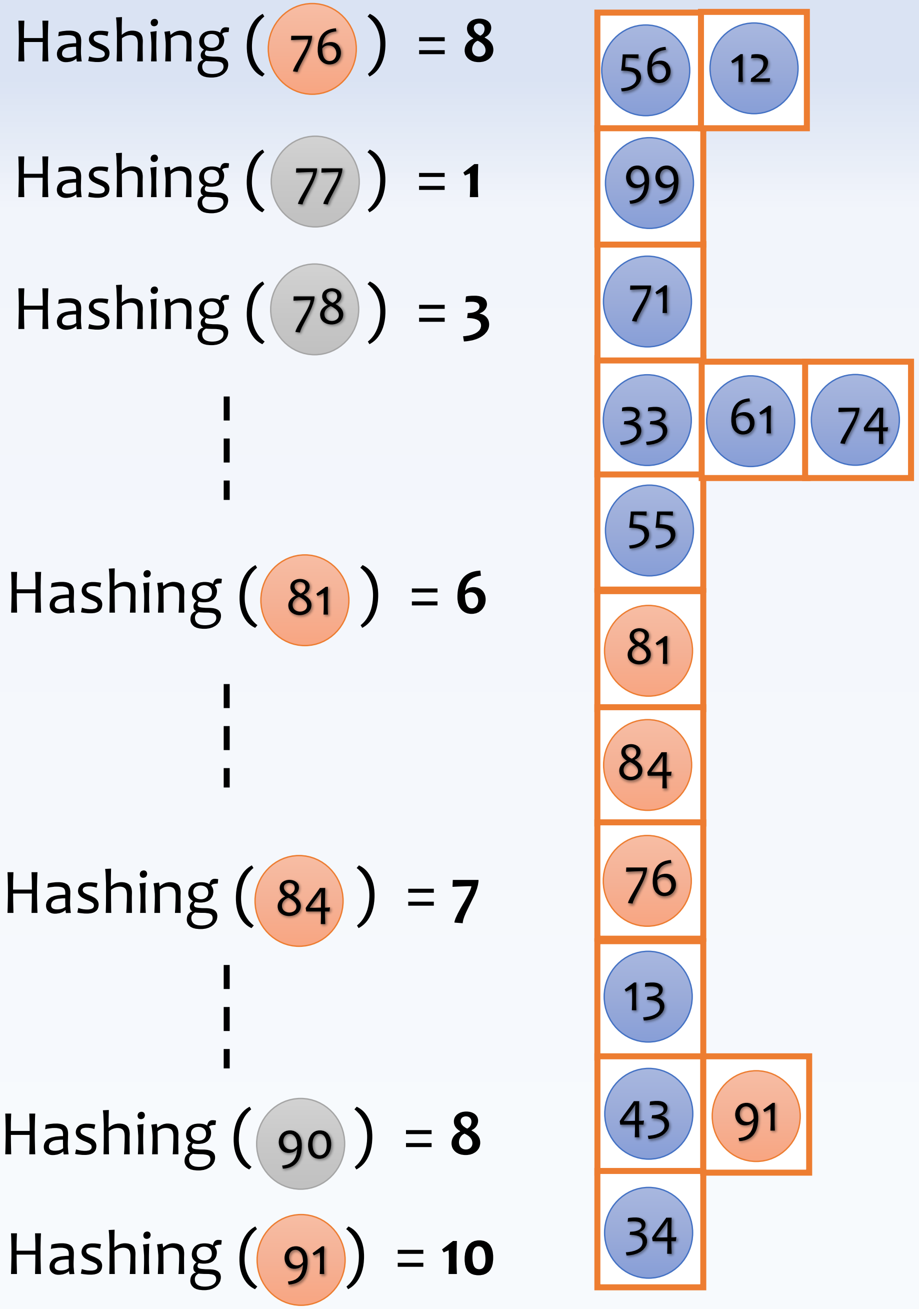
Searching for 76-91

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



Searching for 76-91

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



Hashing (76) = 8

Hashing (77) = 1

Hashing (78) = 3

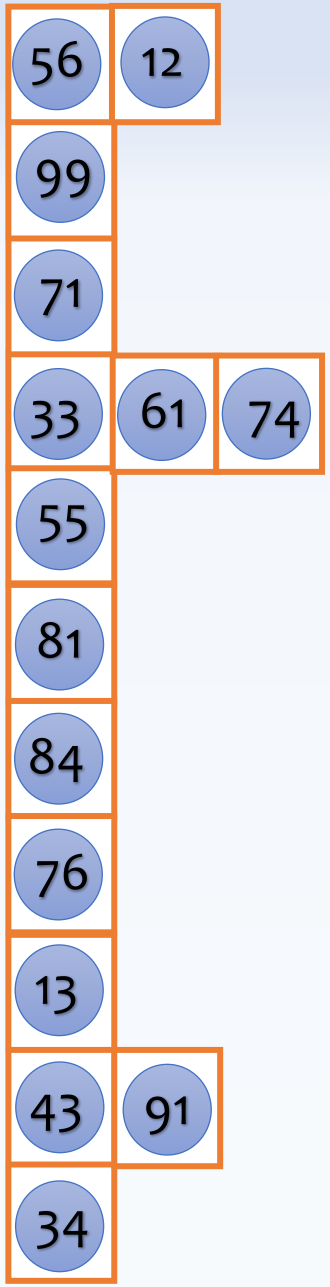
Hashing (81) = 6

Hashing (84) = 7

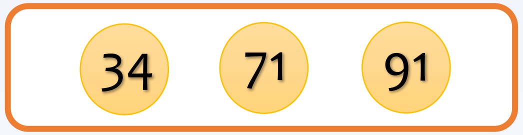
Hashing (90) = 8

Hashing (91) = 10

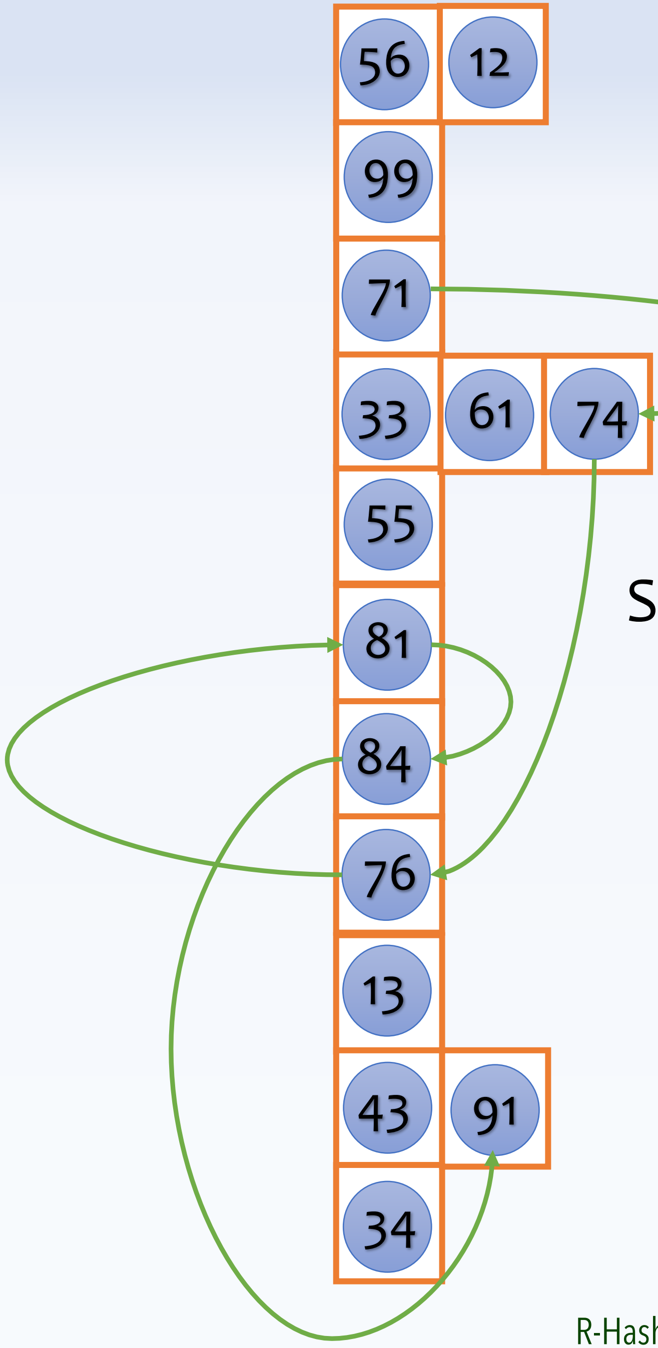
Could we imagine a new design to support searching for a range of values efficiently?



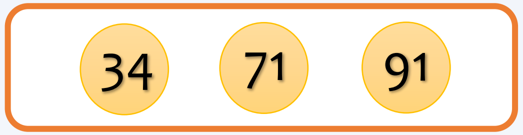
Let’s promote a subset of values as seeds



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



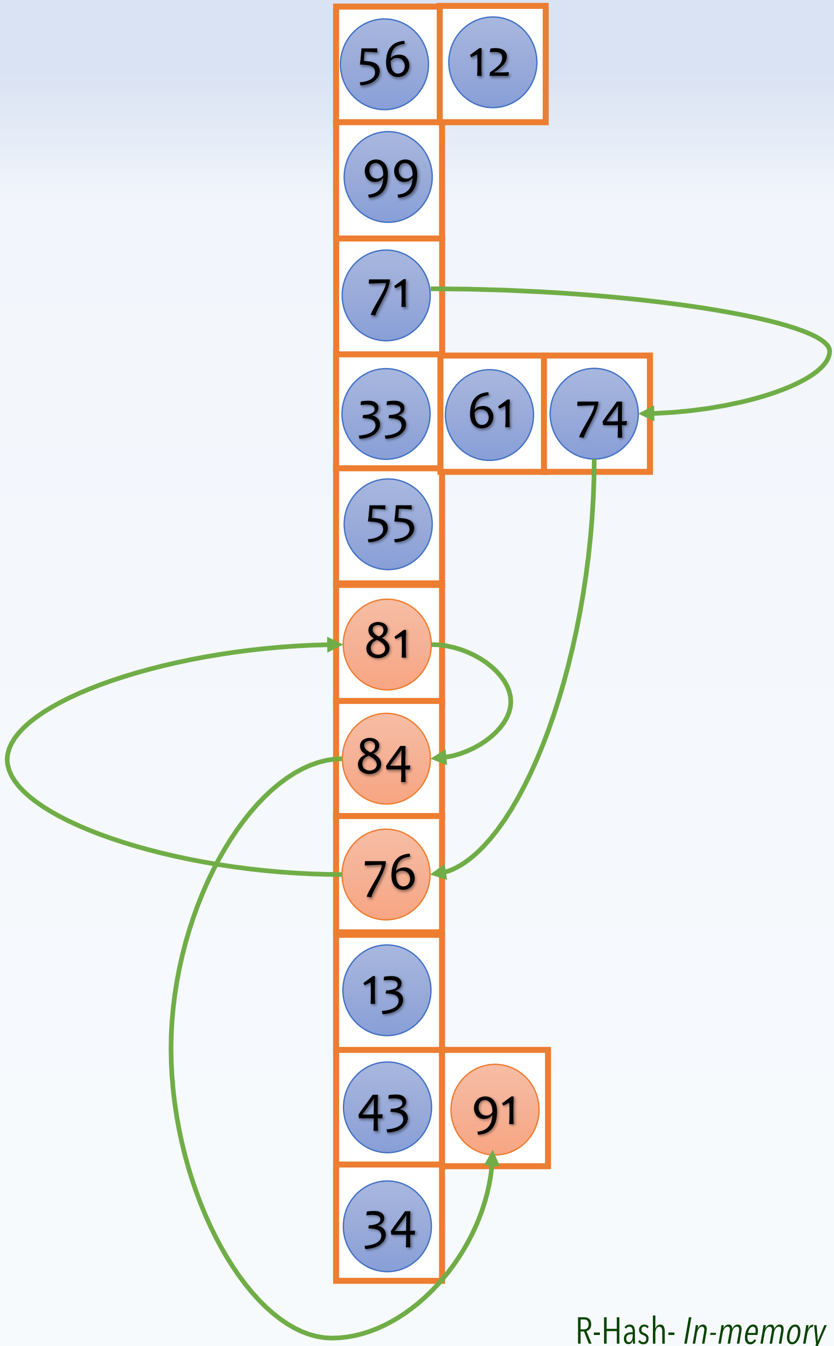
Let’s promote a subset of values as seeds



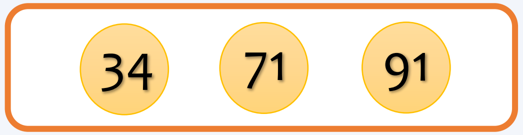
Suppose every value points to its next larger value

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

Searching for 76-91

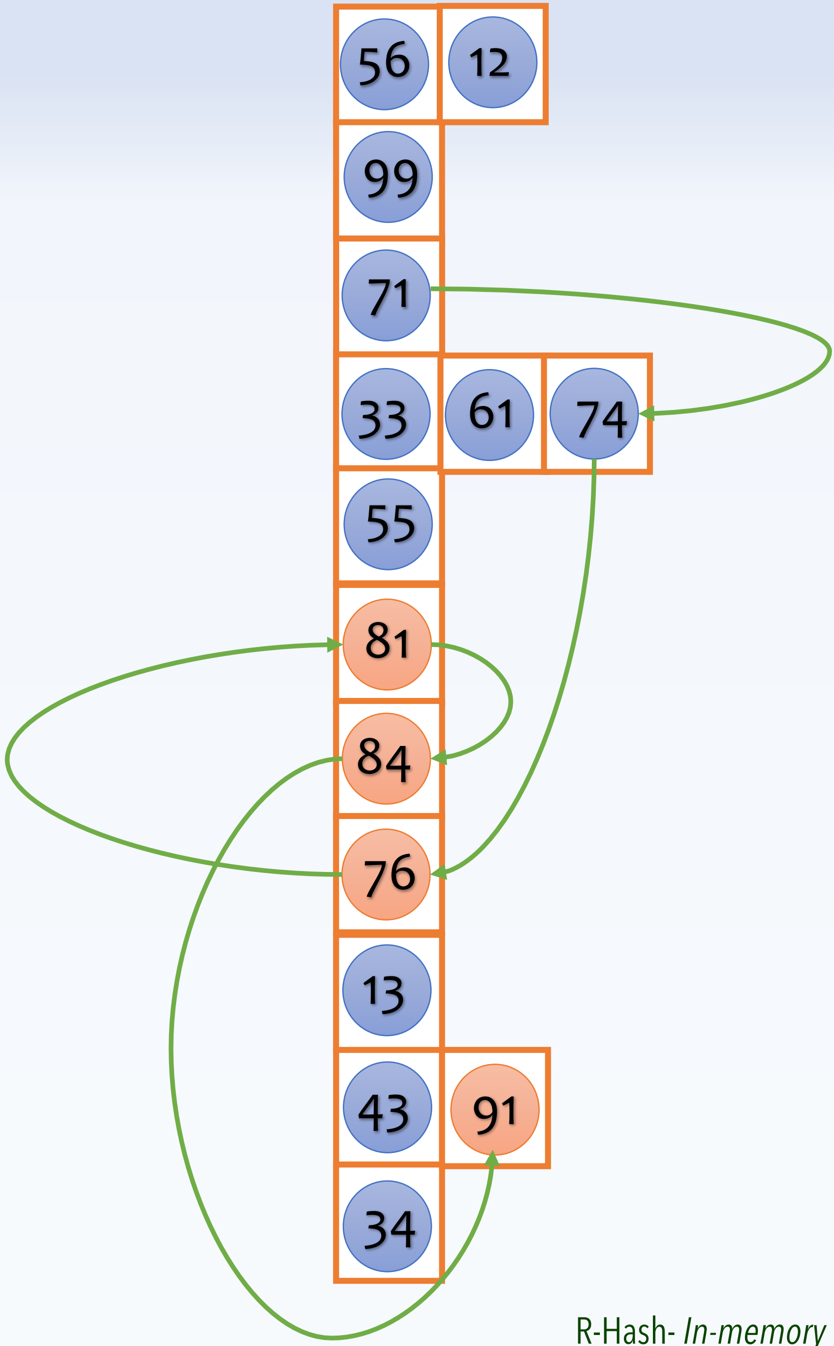


sorted seeds

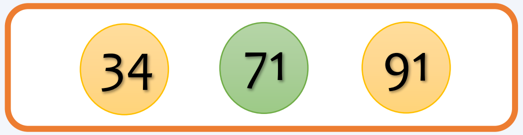


R-Hash- *In-memory latch-free index structure* B Bhattacharjee, M Canim, M. Sadoghi, *US Patent 9,858,303*

Searching for 76-91



sorted seeds

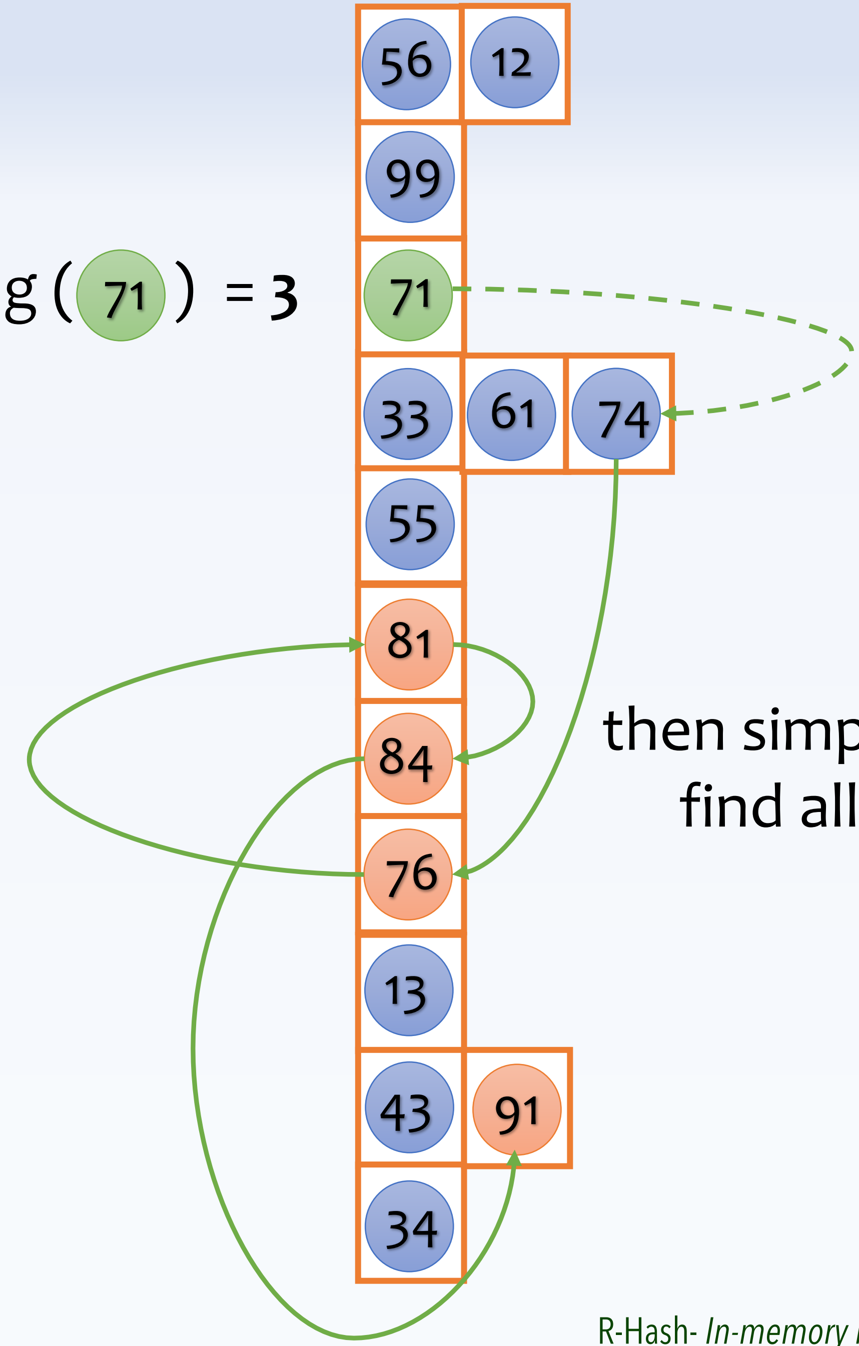


Find the largest seed smaller than 76: 71

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

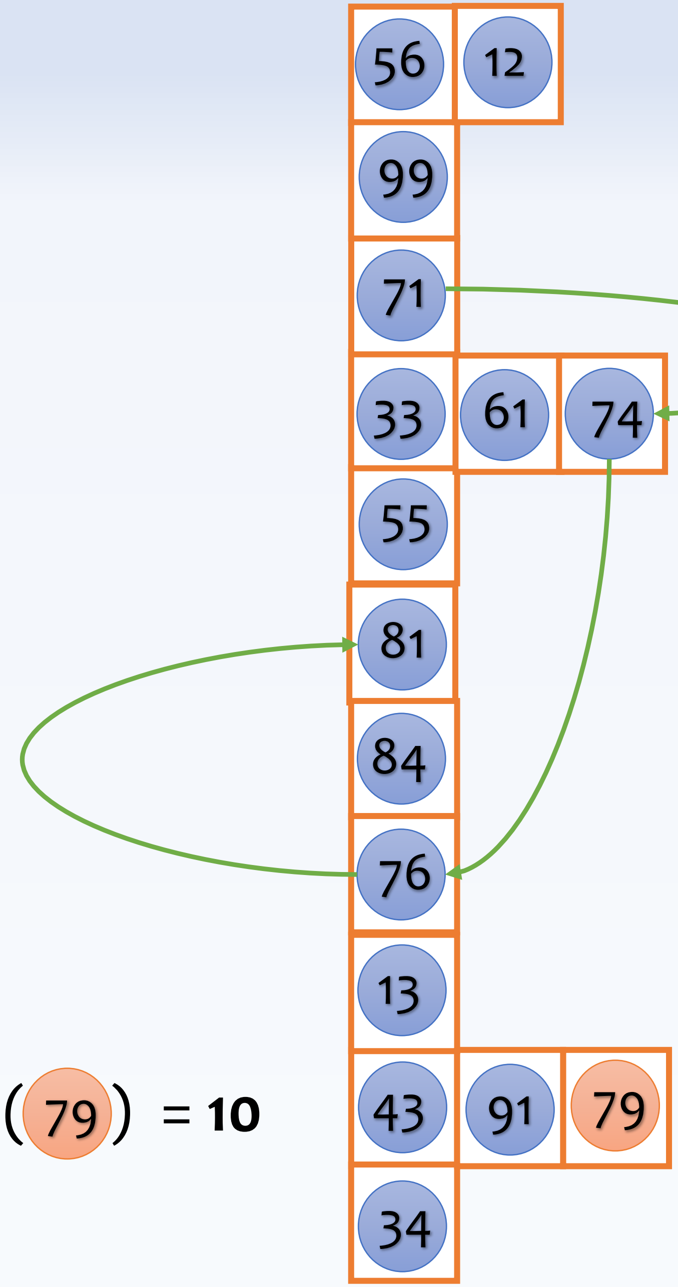
34 71 91

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*

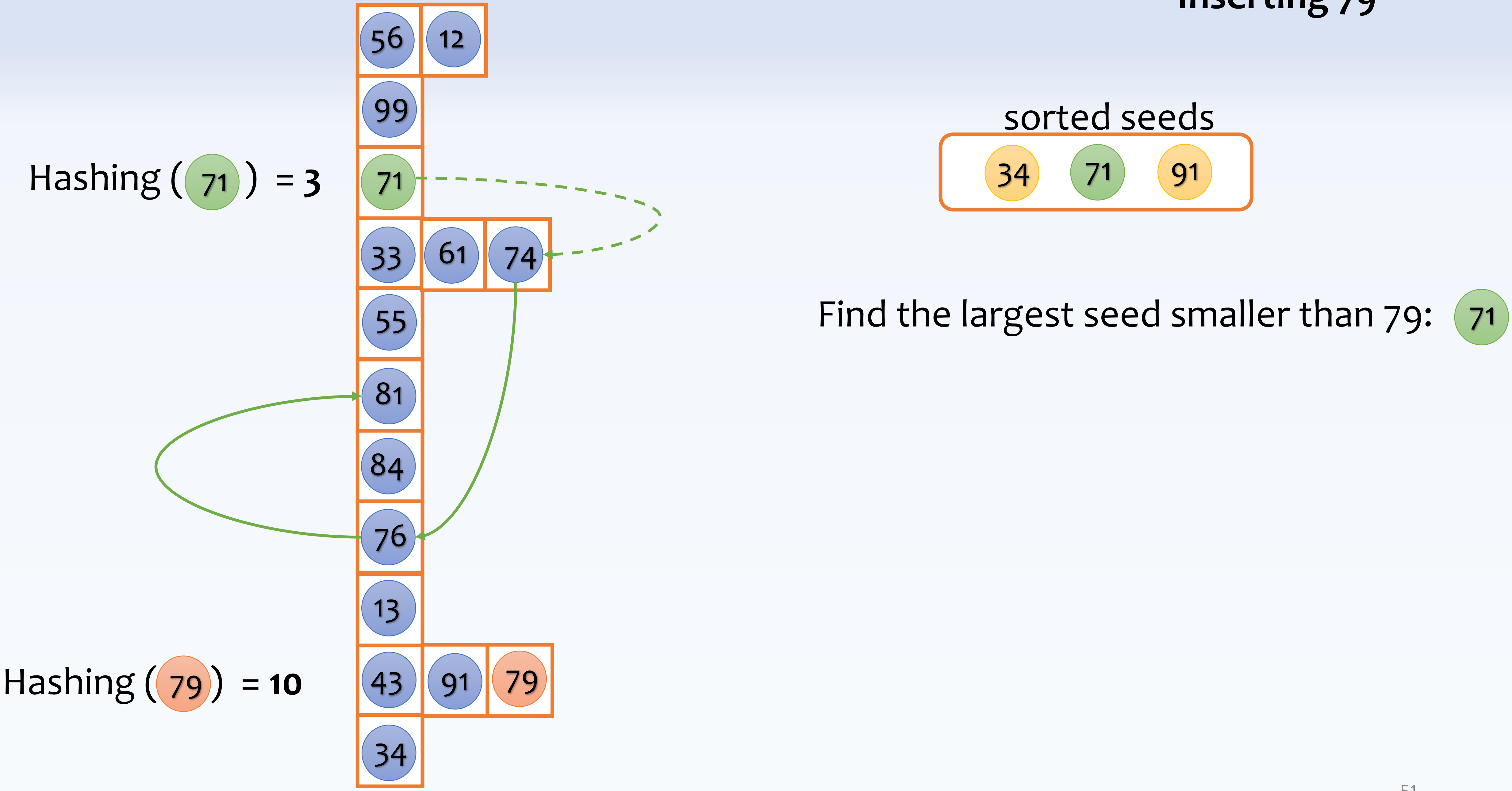
Inserting 79



Hashing (79) = **10**

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

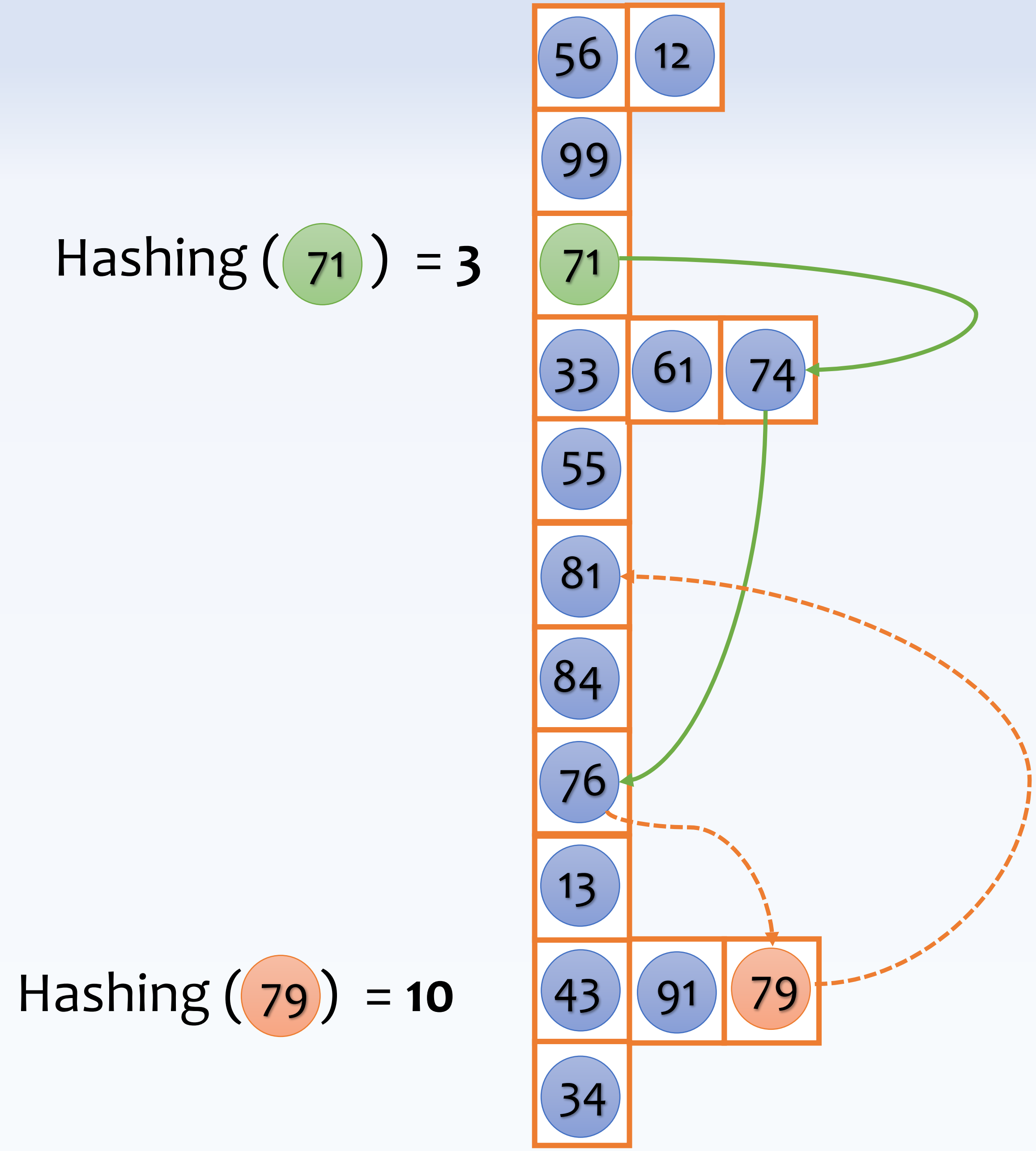
Inserting 79



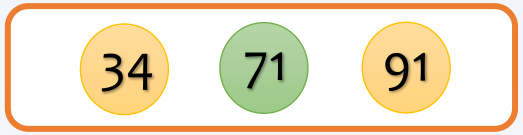
Find the largest seed smaller than 79: 71

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

Inserting 79



sorted seeds

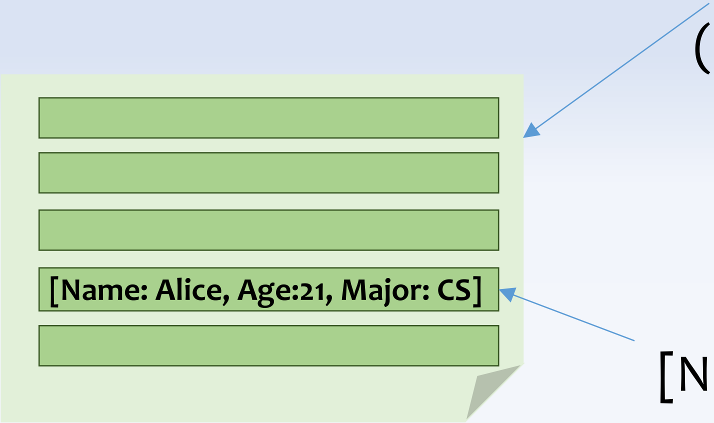


Find the largest seed smaller than 79: 71

adjust the pointers accordingly

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

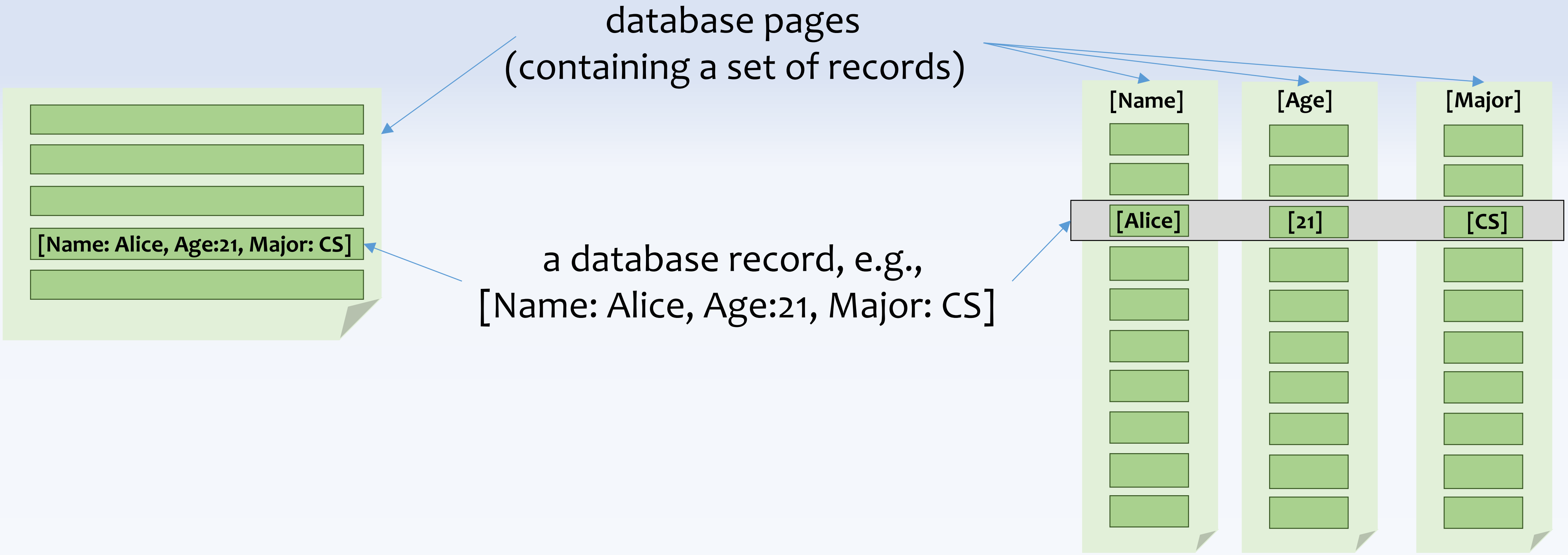
Database Storage Layouts
(how likely that we need an index for range queries?)



database pages
(containing a set of records)

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

Row-based Layout

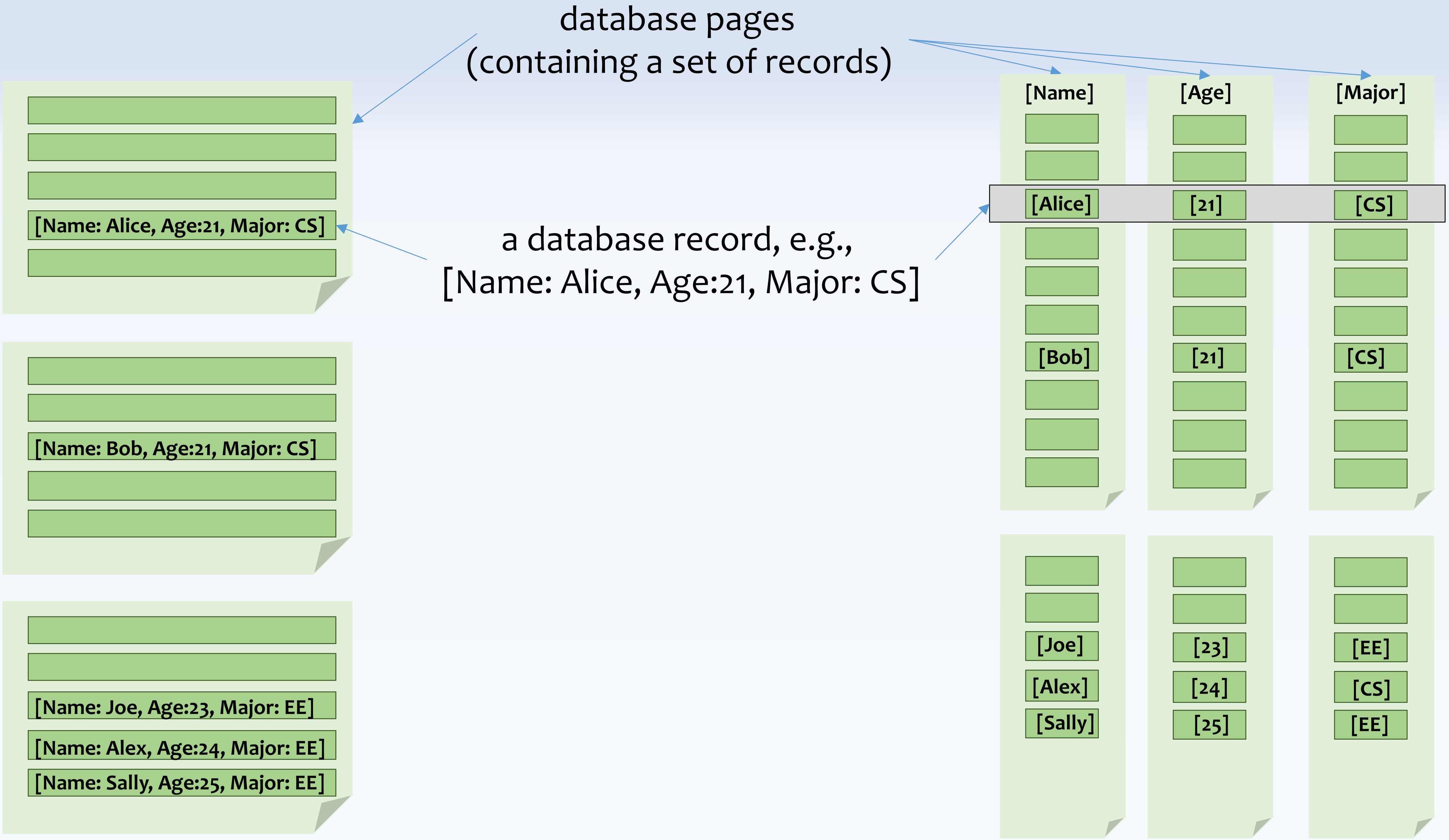


database pages
(containing a set of records)

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

Row-based Layout

Column-based Layout



database pages
(containing a set of records)

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

[Name: Alice, Age:21, Major: CS]
[Name: Bob, Age:21, Major: CS]
[Name: Joe, Age:23, Major: EE]
[Name: Alex, Age:24, Major: EE]
[Name: Sally, Age:25, Major: EE]
[Name]
[Age]
[Major]
[Alice]
[21]
[CS]
[Bob]
[21]
[CS]
[Joe]
[23]
[EE]
[Alex]
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[Sally]
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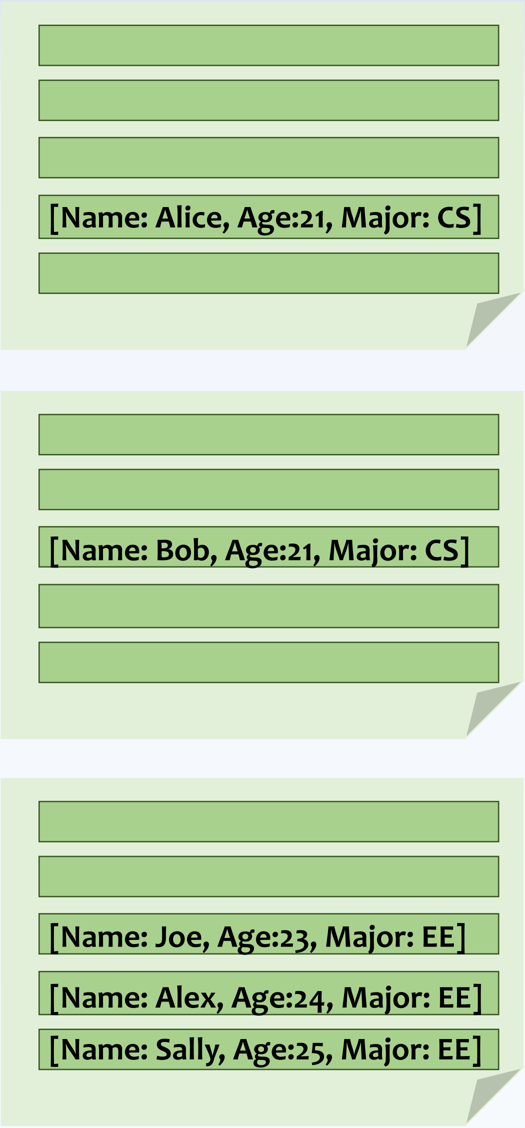
[EE]

Row-based Layout

Column-based Layout

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



[Name: Alice, Age:21, Major: CS]

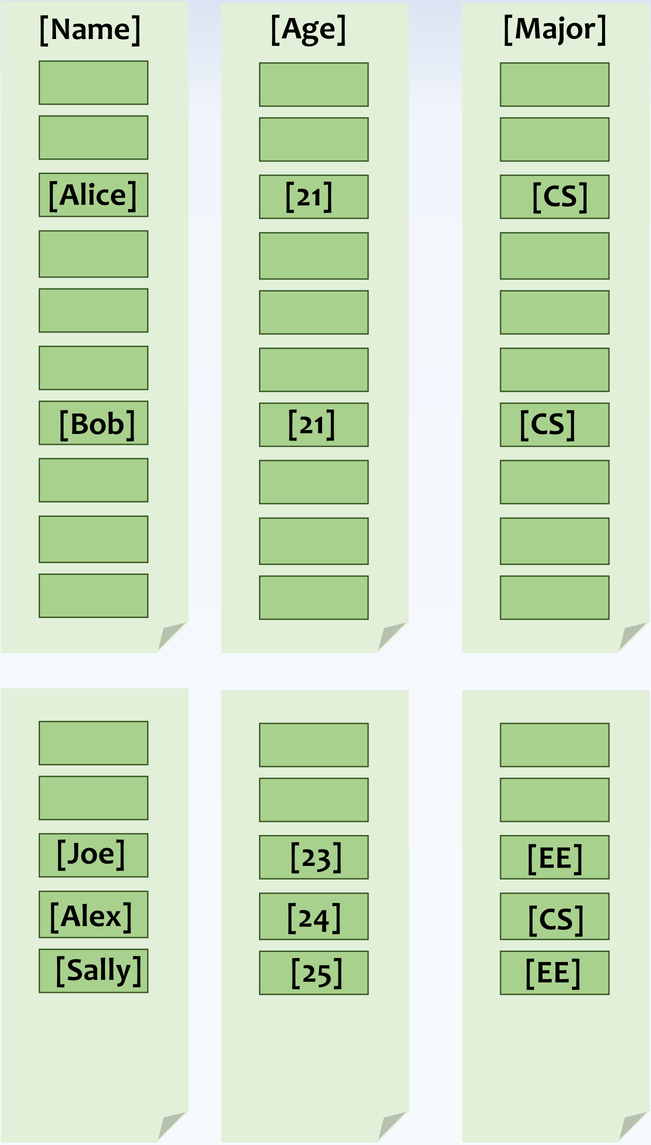
[Name: Bob, Age:21, Major: CS]

[Name: Joe, Age:23, Major: EE]

[Name: Alex, Age:24, Major: EE]

[Name: Sally, Age:25, Major: EE]

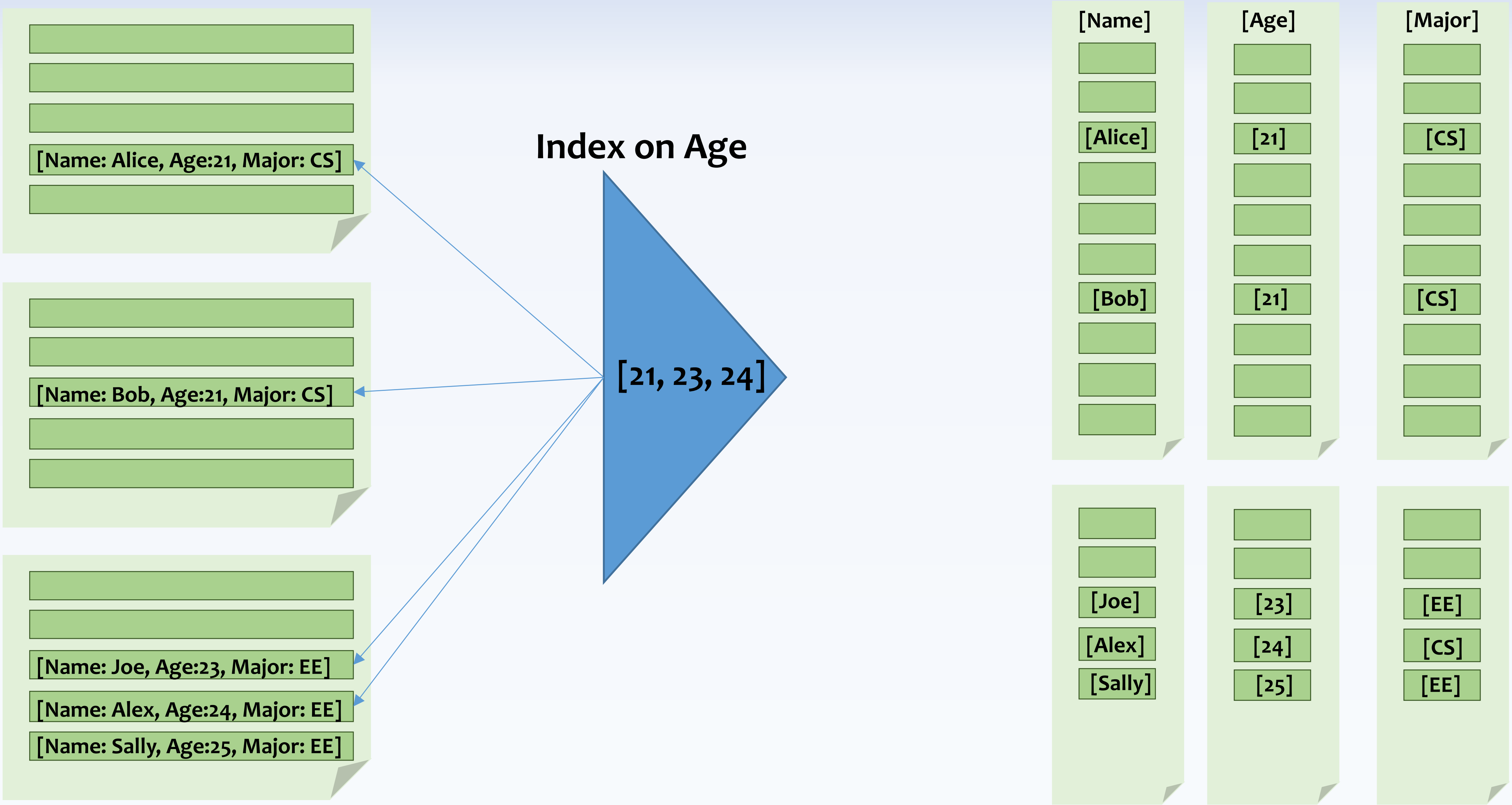
Row-based Layout



[Name]	[Age]	[Major]
[Alice]	[21]	[CS]
[Bob]	[21]	[CS]
[Joe]	[23]	[EE]
[Alex]	[24]	[CS]
[Sally]	[25]	[EE]

Column-based Layout

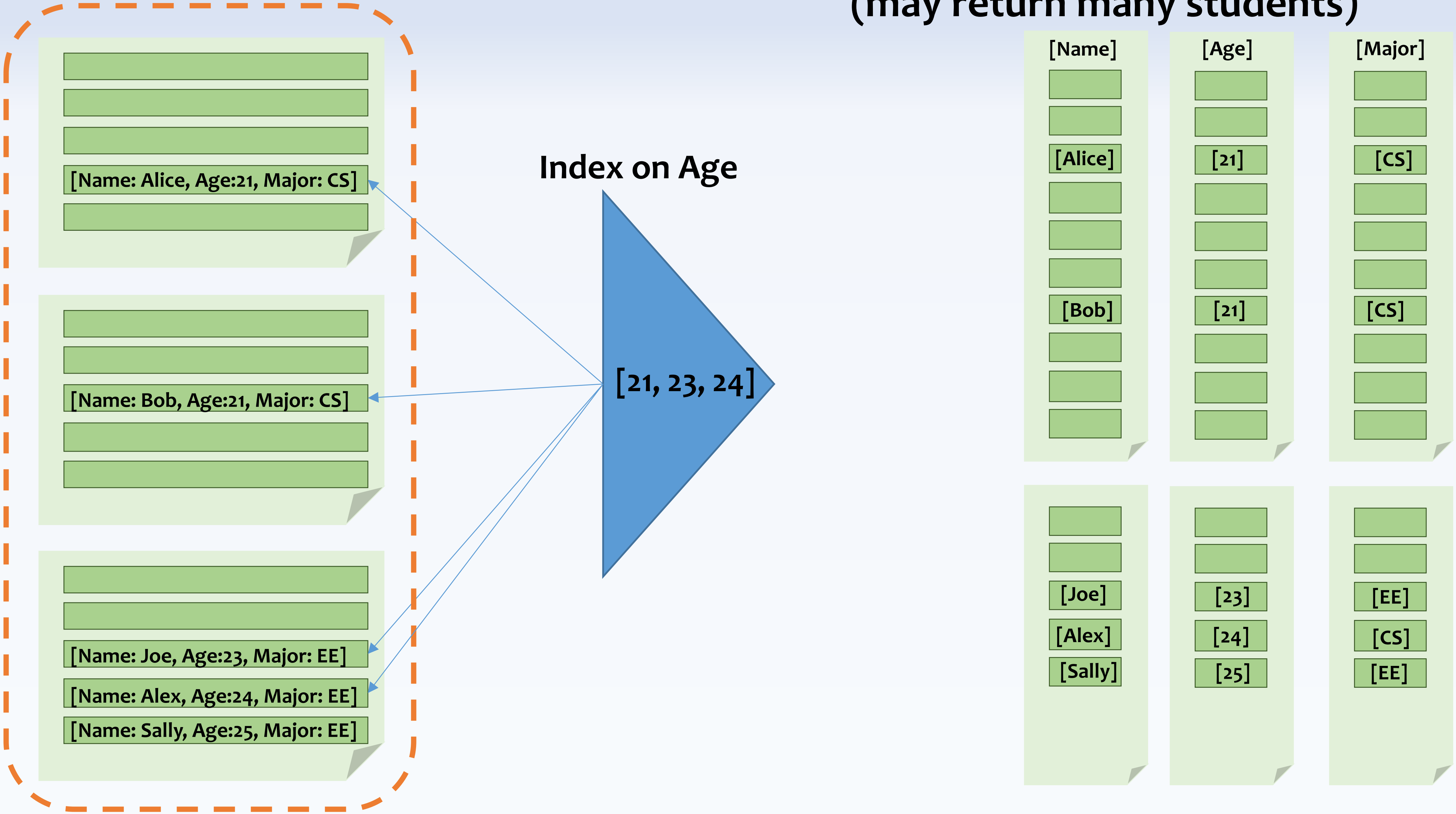
Searching for all students between the age of 21 to 24 (may return many students)


[Name: Alice, Age:21, Major: CS]
[Name: Bob, Age:21, Major: CS]
[Name: Joe, Age:23, Major: EE]
[Name: Alex, Age:24, Major: EE]
[Name: Sally, Age:25, Major: EE]
Index on Age
[21, 23, 24]
[Name]
[Age]
[Major]
[Alice]
[21]
[CS]
[Bob]
[21]
[CS]
[Joe]
[23]
[EE]
[Alex]
[24]
[CS]
[Sally]
[25]
[EE]

Row-based Layout

Column-based Layout

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



[Name: Alice, Age:21, Major: CS]

[Name: Bob, Age:21, Major: CS]

[Name: Joe, Age:23, Major: EE]

[Name: Alex, Age:24, Major: EE]

[Name: Sally, Age:25, Major: EE]

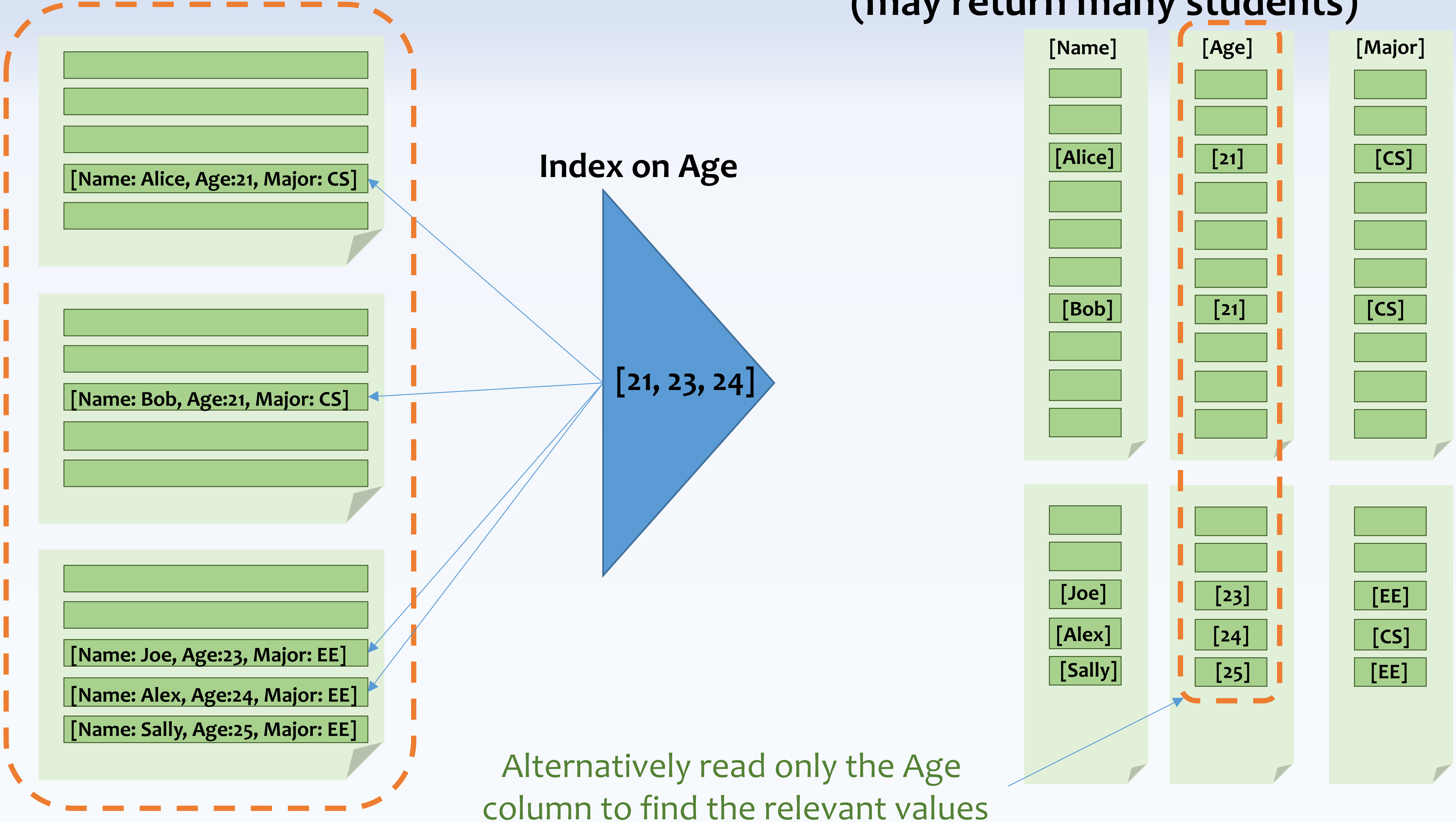
Index on Age

[21, 23, 24]

Row-based Layout

Column-based Layout

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



[Name: Alice, Age:21, Major: CS]

[Name: Bob, Age:21, Major: CS]

[Name: Joe, Age:23, Major: EE]

[Name: Alex, Age:24, Major: EE]

[Name: Sally, Age:25, Major: EE]

Index on Age

[21, 23, 24]

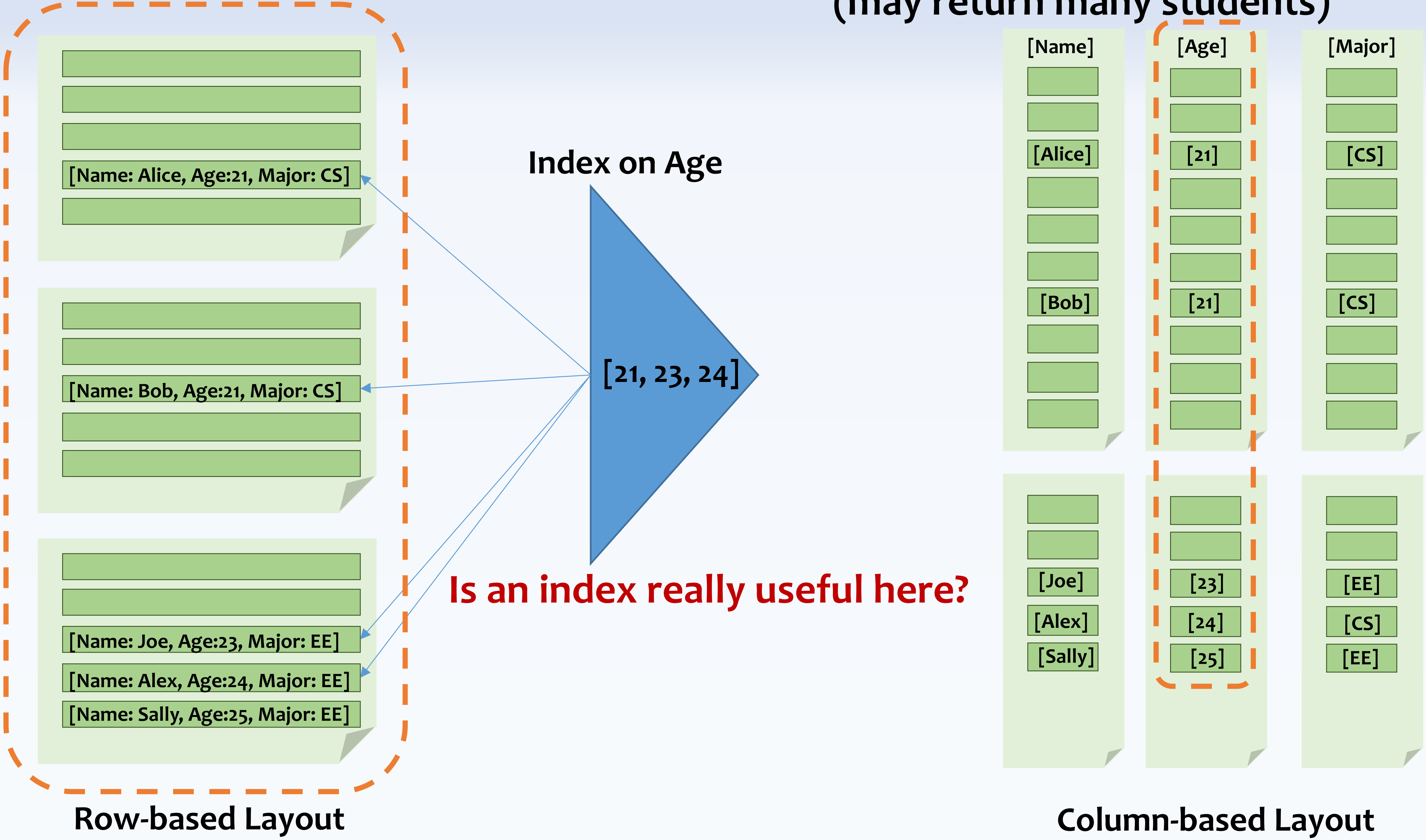
[Name]	[Age]	[Major]
[Alice]	[21]	[CS]
[Bob]	[21]	[CS]
[Joe]	[23]	[EE]
[Alex]	[24]	[CS]
[Sally]	[25]	[EE]

Alternatively read only the Age column to find the relevant values

Row-based Layout

Column-based Layout

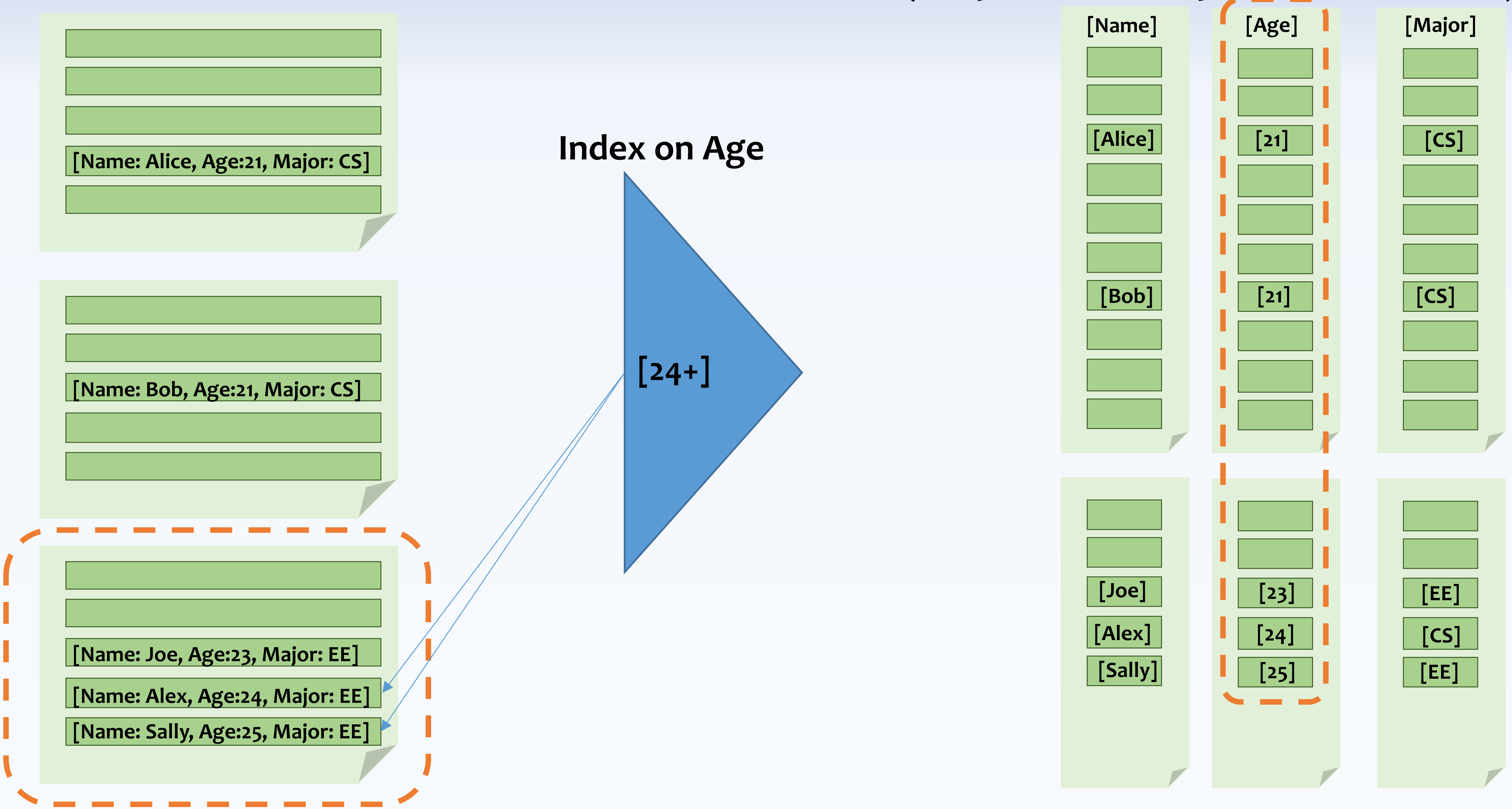
Searching for all students between the age of 21 to 24 (may return many students)



[Name: Alice, Age:21, Major: CS]
[Name: Bob, Age:21, Major: CS]
[Name: Joe, Age:23, Major: EE]
[Name: Alex, Age:24, Major: EE]
[Name: Sally, Age:25, Major: EE]
Row-based Layout
Index on Age
[21, 23, 24]
[Name]
[Alice]
[Bob]
[Joe]
[Alex]
[Sally]
[Age]
[21]
[21]
[23]
[24]
[25]
[Major]
[CS]
[CS]
[EE]
[CS]
[EE]
Column-based Layout

Is an index really useful here?

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



[Name: Alice, Age:21, Major: CS]

[Name: Bob, Age:21, Major: CS]

[Name: Joe, Age:23, Major: EE]

[Name: Alex, Age:24, Major: EE]

[Name: Sally, Age:25, Major: EE]

Index on Age

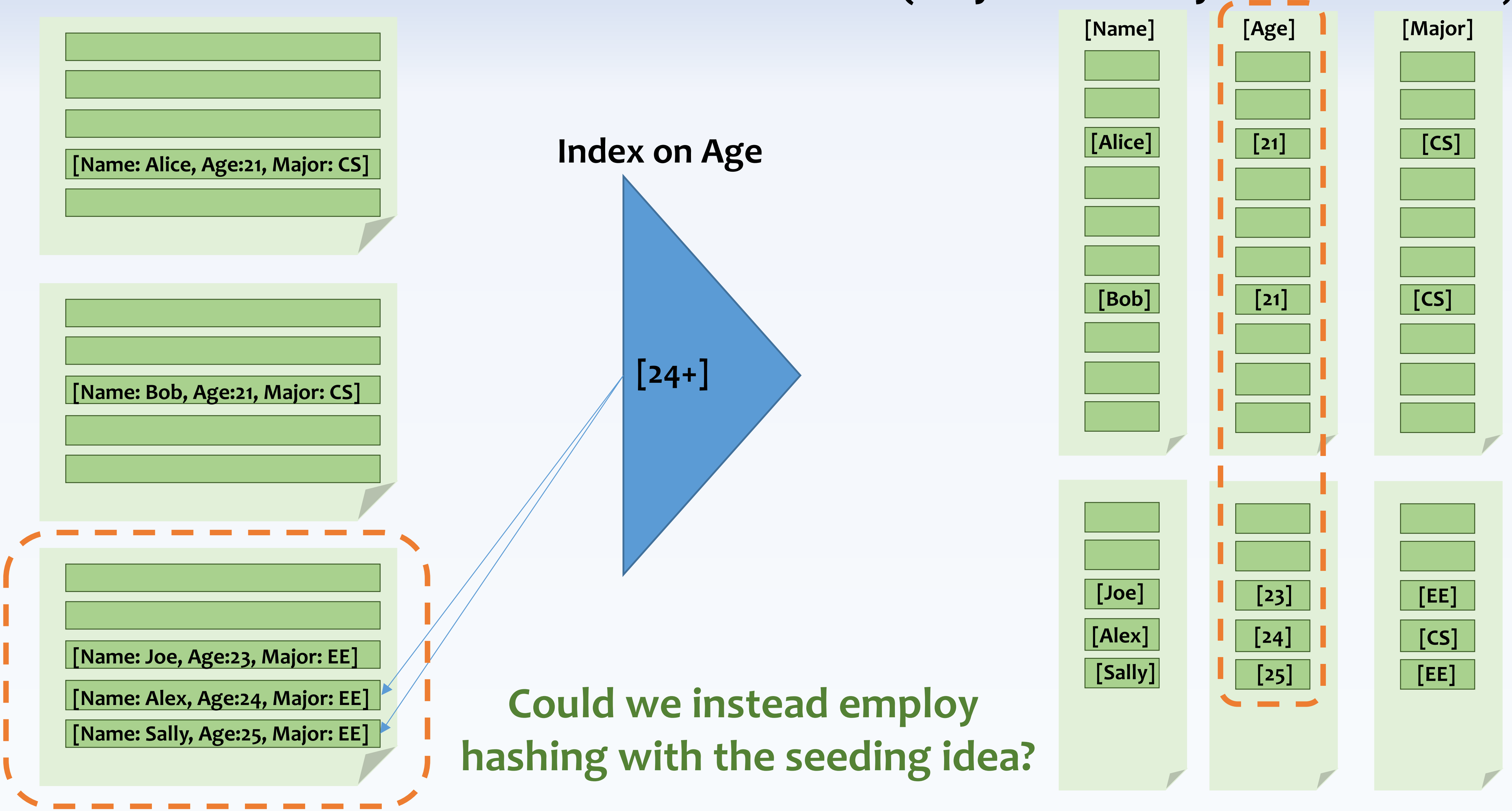
[24+]

[Name]	[Age]	[Major]
[Alice]	[21]	[CS]
[Bob]	[21]	[CS]
[Joe]	[23]	[EE]
[Alex]	[24]	[CS]
[Sally]	[25]	[EE]

Row-based Layout

Column-based Layout

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



[Name: Alice, Age:21, Major: CS]

[Name: Bob, Age:21, Major: CS]

[Name: Joe, Age:23, Major: EE]

[Name: Alex, Age:24, Major: EE]

[Name: Sally, Age:25, Major: EE]

Index on Age

[24+]

[Name]	[Age]	[Major]
[Alice]	[21]	[CS]
[Bob]	[21]	[CS]
[Joe]	[23]	[EE]
[Alex]	[24]	[CS]
[Sally]	[25]	[EE]

Could we instead employ hashing with the seeding idea?

Row-based Layout

Column-based Layout

Thank You
Questions?