

A Ring of Structures

ESC101: Fundamentals of Computing

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Announcements

- This Wednesday (07 Nov, 2018) is an institute holiday
 - No lectures, no labs
 - We have already compensated for this day last Saturday
- Tutorial will be held on Friday 09 Nov as usual
- Course feedback survey has started
<http://oars2.cc.iitk.ac.in:9090/survey2/survey.php>
 - Survey Date : 05 Nov – 16 Nov
 - Can give the survey from halls, CC, NCL, CSE dept

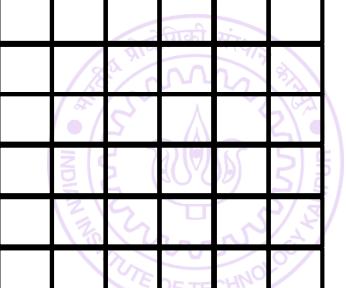


Linked Lists



Linked Lists

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Linked Lists

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Linked Lists

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Linked Lists

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Linked Lists

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Linked Lists

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000025	██████████

Linked Lists

000000	██████████
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Linked Lists

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	0 0 0 0 0 0 0 6
000006	██████████
000007	██████████
000008	██████████
000009	██████████
000010	██████████
000011	██████████
000012	██████████
000013	██████████
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Linked Lists



000000	██████
000001	██████
000002	██████
000003	██████
000004	██████
000005	0 0 0 0 0 0 0 6
000006	██████
000007	██████
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000009	██████
000010	████████
000011	████████
000012	████████
000013	████████
000014	██████
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ESC101: Fundamentals of Computing

Linked Lists

Linked Lists



000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	0 0 0 0 0 0 0 6
000006	██████████
000007	0 0 0 0 0 0 0 8
000008	██████████
000009	██████████
000010	██████████
000011	██████████
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000013	██████████
000014	██████████
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000017	██████████
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000022	██████████
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000025	██████████



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Linked Lists

The diagram illustrates a linked list structure using a grid of colored cells. The columns represent memory addresses, ranging from 000000 to 000025. The rows represent memory locations, with each row containing 8 cells. The colors of the cells indicate different memory types or states:

- Row 0:** Dark grey cells.
- Row 1:** Dark grey cells.
- Row 2:** Dark grey cells.
- Row 3:** Dark grey cells.
- Row 4:** Dark grey cells.
- Row 5:** Light orange cells.
- Row 6:** Light orange cells.
- Row 7:** Light orange cells.
- Row 8:** Light orange cells.
- Row 9:** Light orange cells.
- Row 10:** Light orange cells.
- Row 11:** Light orange cells.
- Row 12:** Light orange cells.
- Row 13:** Light orange cells.
- Row 14:** Light orange cells.
- Row 15:** Light orange cells.
- Row 16:** Light orange cells.
- Row 17:** Light orange cells.
- Row 18:** Light blue cells.
- Row 19:** Light blue cells.
- Row 20:** Light blue cells.
- Row 21:** Light blue cells.
- Row 22:** Light blue cells.
- Row 23:** Light blue cells.
- Row 24:** Light blue cells.
- Row 25:** Light blue cells.

Two specific nodes are highlighted with red arrows and circles:

- Node 5:** Located at address 000005, the value is 0000000000000006. A red arrow points to the value, and a red circle highlights the entire row.
- Node 6:** Located at address 000006, the value is 0000000000000000. A red arrow points to the value, and a red circle highlights the entire row.
- Node 7:** Located at address 000007, the value is 0000000000000008. A red arrow points to the value, and a red circle highlights the entire row.
- Node 8:** Located at address 000008, the value is 0000000000000000. A red arrow points to the value, and a red circle highlights the entire row.

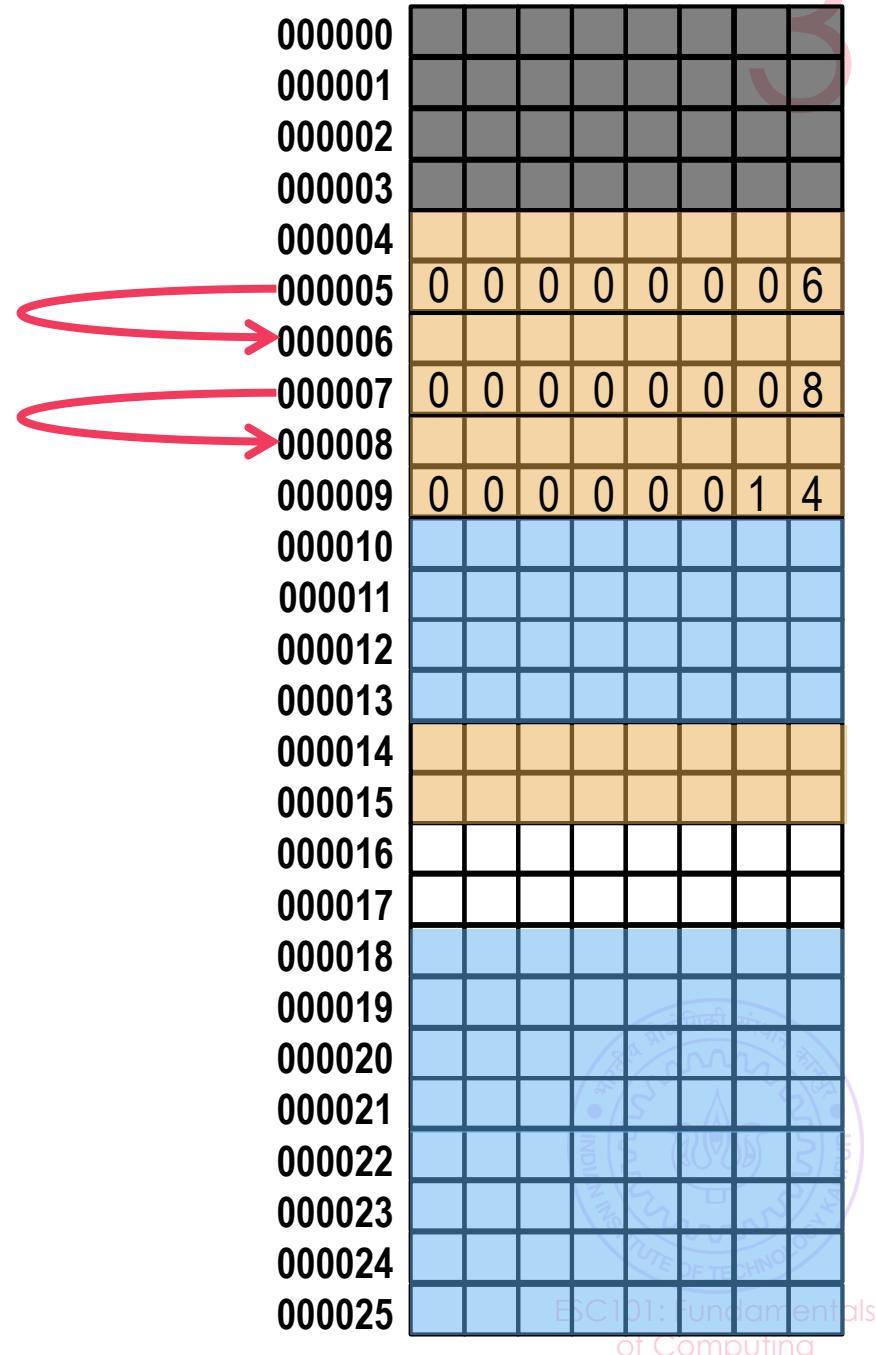
A faint watermark of the Indian Institute of Technology Roorkee logo is visible in the background of the grid.

Linked Lists

000000	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
000001																									
000002																									
000003																									
000004																									
000005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
000006																									
000007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
000008																									
000009																									
000010																									
000011																									
000012																									
000013																									
000014																									
000015																									
000016																									
000017																									
000018																									
000019																									
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000024																									
000025																									

ESC101: Fundamentals of Computing

Linked Lists



The diagram illustrates a linked list structure using a grid of colored cells. The vertical axis on the left lists indices from 000000 to 000025. Red arrows point from the labels 000005, 000006, 000007, and 000008 to their corresponding cells in the grid. Red circles highlight the first four rows of the grid, which contain binary data: 000005 has a value of 6, 000006 has a value of 8, 000007 has a value of 14, and 000008 has a value of 4. The remaining rows (000009 to 000025) have varying patterns of gray, orange, blue, and white cells.

000000	Gray																												
000001	Gray																												
000002	Gray																												
000003	Gray																												
000004	Orange																												
000005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	
000006	Orange																												
000007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	
000008	Orange																												
000009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0
000010	Blue																												
000011	Blue																												
000012	Blue																												
000013	Blue																												
000014	Orange																												
000015	Orange																												
000016	White																												
000017	White																												
000018	Blue																												
000019	Blue																												
000020	Blue																												
000021	Blue																												
000022	Blue																												
000023	Blue																												
000024	Blue																												
000025	Blue																												

Linked Lists

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	00000006
000006	██████████
000007	00000008
000008	██████████
000009	00000014
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	██████████
000016	██████████
000017	██████████
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

Linked Lists

000000	5
000001	
000002	
000003	
000004	
000005	0 0 0 0 0 0 0 6
000006	
000007	0 0 0 0 0 0 0 8
000008	
000009	0 0 0 0 0 0 0 1 4
000010	
000011	
000012	
000013	
000014	
000015	
000016	
000017	
000018	
000019	
000020	
000021	
000022	
000023	
000024	
000025	

Linked Lists

Linked Lists

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	0 0 0 0 0 0 0 6
000006	██████████
000007	0 0 0 0 0 0 0 8
000008	██████████
000009	0 0 0 0 0 0 1 4
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	0 0 0 0 0 0 0 1 6
000016	██████████
000017	██████████
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

Linked Lists

000000	000001	000002	000003	000004	000005	000006	000007
000001	000002	000003	000004	000005	000006	000007	000008
000002	000003	000004	000005	000006	000007	000008	000009
000003	000004	000005	000006	000007	000008	000009	000010
000004	000005	000006	000007	000008	000009	000010	000011
000005	000006	000007	000008	000009	000010	000011	000012
000006	000007	000008	000009	000010	000011	000012	000013
000007	000008	000009	000010	000011	000012	000013	000014
000008	000009	000010	000011	000012	000013	000014	000015
000009	000010	000011	000012	000013	000014	000015	000016
000010	000011	000012	000013	000014	000015	000016	000017
000011	000012	000013	000014	000015	000016	000017	000018
000012	000013	000014	000015	000016	000017	000018	000019
000013	000014	000015	000016	000017	000018	000019	000020
000014	000015	000016	000017	000018	000019	000020	000021
000015	000016	000017	000018	000019	000020	000021	000022
000016	000017	000018	000019	000020	000021	000022	000023
000017	000018	000019	000020	000021	000022	000023	000024
000018	000019	000020	000021	000022	000023	000024	000025
000019	000020	000021	000022	000023	000024	000025	ESC101: Fundamentals of Computing

Linked Lists

Allow for more efficient
usage of space

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

The diagram illustrates a linked list structure using a grid of 25 rows and 8 columns. Each row is labeled with a unique identifier from 000000 to 000025. The columns are color-coded: columns 1 through 4 are dark grey, columns 5 through 8 are orange, and columns 9 through 12 are blue. Red arrows point from row 5 to row 16, highlighting the sequence of pointers. Row 5 contains the value 6 in its 8th column. Row 6 contains the value 8 in its 8th column. Row 9 contains the value 4 in its 8th column. Row 10 is entirely blue. Row 15 contains the value 16 in its 8th column. Row 16 is entirely orange. Row 17 contains the value 0 in its 8th column. Row 18 is entirely blue. Row 25 contains the text "ESC101: Fundamentals of Computing" in its 8th column.

000000								
000001								
000002								
000003								
000004								
000005	0	0	0	0	0	0	0	6
000006								
000007	0	0	0	0	0	0	0	8
000008								
000009	0	0	0	0	0	0	1	4
000010								
000011								
000012								
000013								
000014								
000015	0	0	0	0	0	0	0	16
000016								
000017	0	0	0	0	0	0	0	0
000018								
000019								
000020								
000021								
000022								
000023								
000024								
000025								

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

Allow as many elements as you want

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	0 0 0 0 0 0 0 6
000006	██████████
000007	0 0 0 0 0 0 0 8
000008	██████████
000009	0 0 0 0 0 0 1 4
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	0 0 0 0 0 0 0 1 6
000016	██████████
000017	0 0 0 0 0 0 0 0
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

ESC101: Fundamentals of Computing

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

Allow as many elements as you want

Do not require contiguous space to be available – pack things better

000000							
000001							
000002							
000003							
000004							
000005	0	0	0	0	0	0	0
000006							
000007	0	0	0	0	0	0	0
000008							
000009	0	0	0	0	0	0	1
000010							
000011							
000012							
000013							
000014							
000015	0	0	0	0	0	0	1
000016							
000017	0	0	0	0	0	0	0
000018							
000019							
000020							
000021							
000022							
000023							
000024							
000025							

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

Allow as many elements as you want

Do not require contiguous space to be available – pack things better

Can expand without calling realloc

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	00000006
000006	██████████
000007	00000008
000008	██████████
000009	000000014
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	000000016
000016	██████████
000017	000000000
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

- Allow as many elements as you want
- Do not require contiguous space to be available – pack things better
- Can expand without calling realloc
- Inserting in the middle very simple

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	00000006
000006	██████████
000007	00000008
000008	██████████
000009	00000014
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	000000016
000016	██████████
000017	000000000
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

Linked Lists

Allow for more efficient
usage of space

ADVANTAGES

- Allow as many elements as you want
- Do not require contiguous space to be available – pack things better
- Can expand without calling realloc
- Inserting in the middle very simple

DISADVANTAGES

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

- Allow as many elements as you want
- Do not require contiguous space to be available – pack things better
- Can expand without calling realloc
- Inserting in the middle very simple

DISADVANTAGES

- No convenient “names” for elements

The diagram shows a grid of 25 memory addresses (000000 to 000025) and their corresponding values. Red arrows and circles highlight specific elements:

- Row 5: Address 000005 contains 0000000000000006. A red arrow points to the last digit '6'.
- Row 6: Address 000006 contains 0000000000000000. A red arrow points to the last digit '0'.
- Row 7: Address 000007 contains 0000000000000008. A red arrow points to the last digit '8'.
- Row 8: Address 000008 contains 0000000000000000. A red arrow points to the last digit '0'.
- Row 9: Address 000009 contains 000000000000014. A red arrow points to the last digit '4'.
- Row 10: Address 000010 contains 0000000000000000. A red circle highlights the entire row.
- Row 11: Address 000011 contains 0000000000000000. A red circle highlights the entire row.
- Row 12: Address 000012 contains 0000000000000000. A red circle highlights the entire row.
- Row 13: Address 000013 contains 0000000000000000. A red circle highlights the entire row.
- Row 14: Address 000014 contains 0000000000000000. A red arrow points to the last digit '0'.
- Row 15: Address 000015 contains 00000000000000016. A red arrow points to the last digit '6'.
- Row 16: Address 000016 contains 0000000000000000. A red arrow points to the last digit '0'.
- Row 17: Address 000017 contains 0000000000000000. A red circle highlights the entire row.
- Row 18: Address 000018 contains 0000000000000000. A red circle highlights the entire row.
- Row 19: Address 000019 contains 0000000000000000. A red circle highlights the entire row.
- Row 20: Address 000020 contains 0000000000000000. A red circle highlights the entire row.
- Row 21: Address 000021 contains 0000000000000000. A red circle highlights the entire row.
- Row 22: Address 000022 contains 0000000000000000. A red circle highlights the entire row.
- Row 23: Address 000023 contains 0000000000000000. A red circle highlights the entire row.
- Row 24: Address 000024 contains 0000000000000000. A red circle highlights the entire row.
- Row 25: Address 000025 contains 0000000000000000. A red circle highlights the entire row.

Each row represents an element in a linked list. The values are packed into 8 bytes (64 bits). The first byte of each row is highlighted in orange, while the rest of the row is blue. The last byte of each row is highlighted in orange, indicating it contains a null terminator ('0').

000000	0000000000000000
000001	0000000000000000
000002	0000000000000000
000003	0000000000000000
000004	0000000000000000
000005	0000000000000006
000006	0000000000000000
000007	0000000000000008
000008	0000000000000000
000009	000000000000014
000010	0000000000000000
000011	0000000000000000
000012	0000000000000000
000013	0000000000000000
000014	0000000000000000
000015	00000000000000016
000016	0000000000000000
000017	0000000000000000
000018	0000000000000000
000019	0000000000000000
000020	0000000000000000
000021	0000000000000000
000022	0000000000000000
000023	0000000000000000
000024	0000000000000000
000025	0000000000000000

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

- Allow as many elements as you want
- Do not require contiguous space to be available – pack things better
- Can expand without calling realloc
- Inserting in the middle very simple

DISADVANTAGES

- No convenient “names” for elements
- Accessing n-th element slow – require going through first n-1 elements

The diagram shows a grid of 25 rows and 8 columns. Each row is labeled with a 5-digit ID from 00000 to 00025 on the left. Red arrows point from each row's ID to its corresponding row in the grid. The grid cells are colored in a repeating pattern: grey, orange, blue, and light blue. Some cells contain numerical values (e.g., 6, 8, 14, 16, 0). A red circle highlights the cell at row 00014, column 7, which contains the value 16. The background features a faint watermark of the Indian Institute of Technology Madras logo.

000000	grey						
000001	grey						
000002	grey						
000003	grey						
000004	orange						
000005	0	0	0	0	0	0	0 6
000006	orange						
000007	0	0	0	0	0	0	0 8
000008	orange						
000009	0	0	0	0	0	0 1	4
000010	blue						
000011	blue						
000012	blue						
000013	blue						
000014	orange						
000015	0	0	0	0	0	0	0 1 6
000016	orange						
000017	0	0	0	0	0	0 0	0
000018	blue						
000019	blue						
000020	blue						
000021	blue						
000022	blue						
000023	blue						
000024	blue						
000025	blue						

Linked Lists

Allow for more efficient usage of space

ADVANTAGES

- Allow as many elements as you want
- Do not require contiguous space to be available – pack things better
- Can expand without calling realloc
- Inserting in the middle very simple

DISADVANTAGES

- No convenient “names” for elements
- Accessing n-th element slow – require going through first n-1 elements
- Setting them up requires more work

The diagram shows a grid of memory cells (rows 000000 to 000025) divided into four color-coded sections: dark grey (top-left), orange (top-right), blue (bottom-left), and light blue (bottom-right). Red arrows point from the labels 000005, 000006, 000007, 000008, 000009, 000010, 000011, 000012, 000013, 000014, 000015, and 000016 to their corresponding cells in the orange section. A large red circle highlights the area containing cells 000014, 000015, and 000016.

000000	██████████
000001	██████████
000002	██████████
000003	██████████
000004	██████████
000005	00000006
000006	██████████
000007	00000008
000008	██████████
000009	00000014
000010	██████████
000011	██████████
000012	██████████
000013	██████████
000014	██████████
000015	00000016
000016	██████████
000017	00000000
000018	██████████
000019	██████████
000020	██████████
000021	██████████
000022	██████████
000023	██████████
000024	██████████
000025	██████████

A Cartoon of Linked Lists

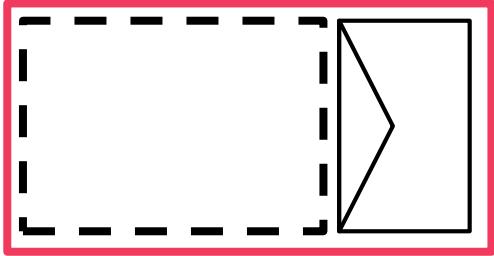
4



ESC101: Fundamentals
of Computing

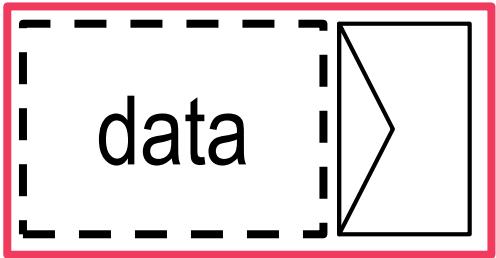
A Cartoon of Linked Lists

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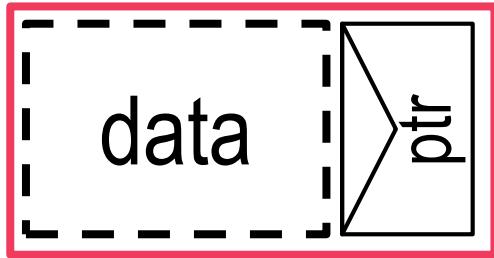


A Cartoon of Linked Lists

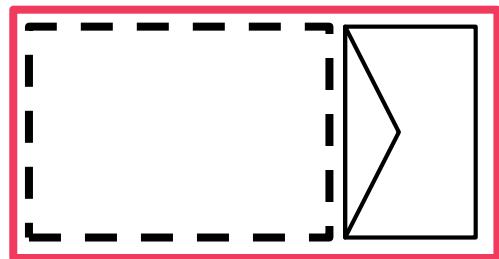
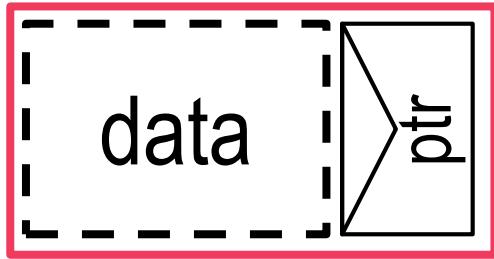
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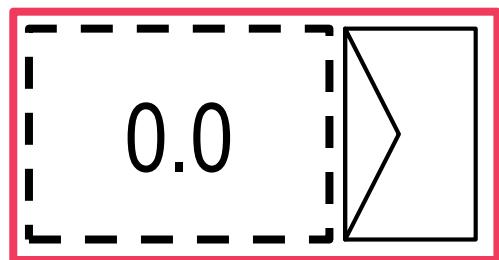
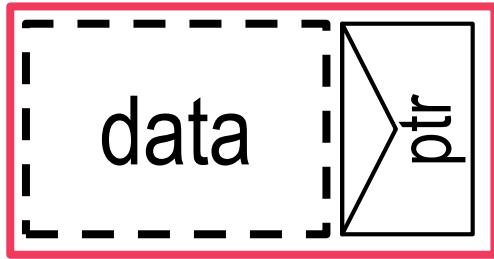
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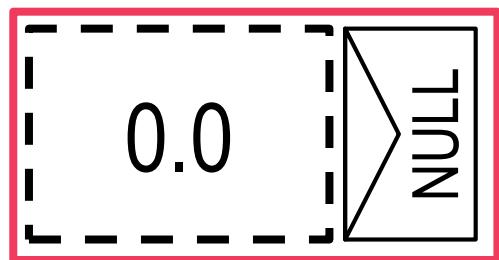
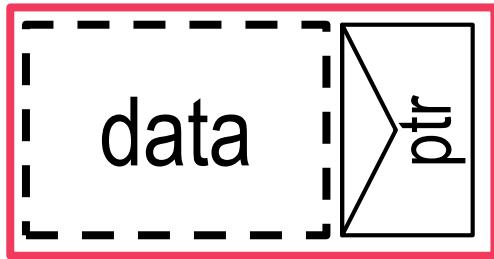
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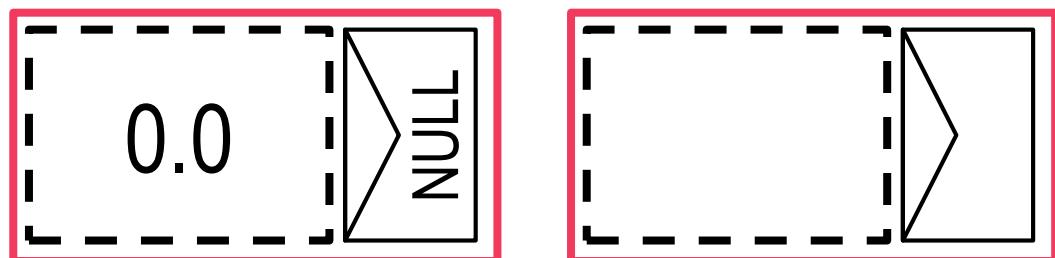
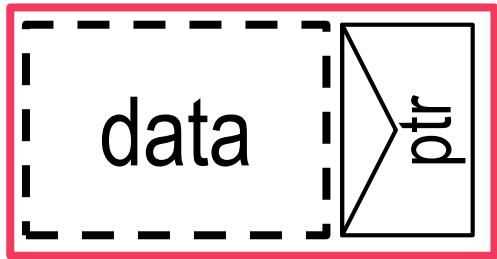
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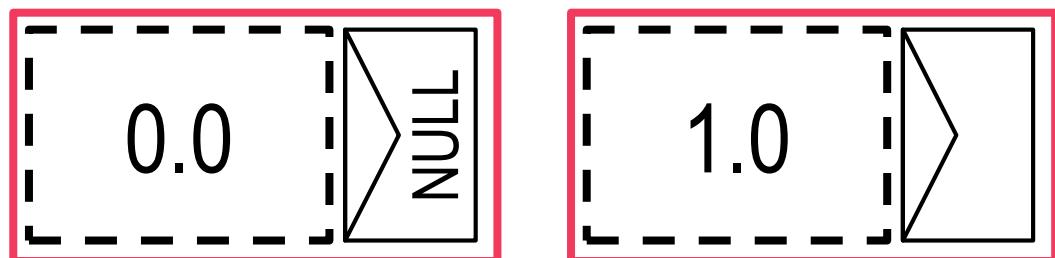
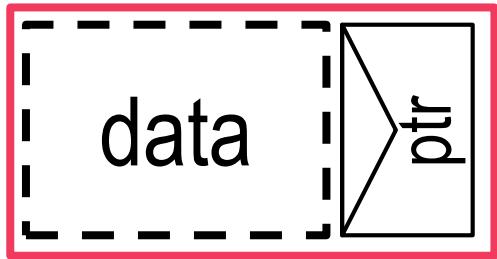
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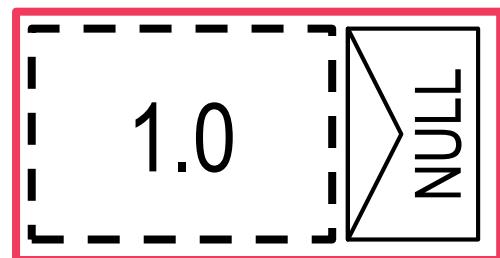
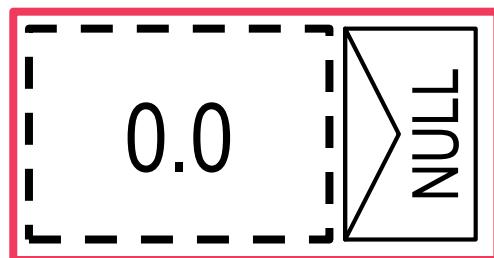
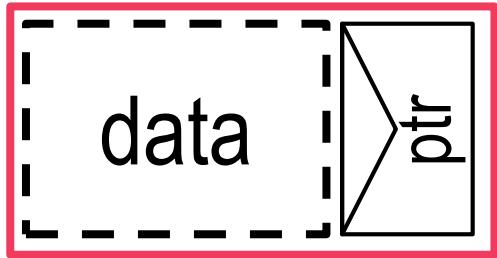
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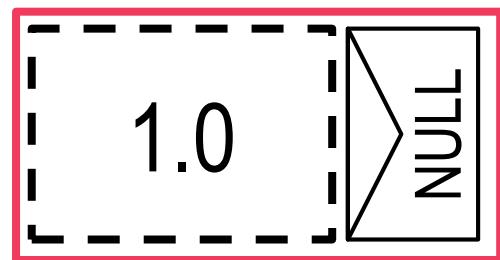
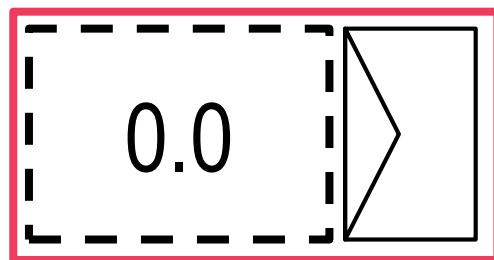
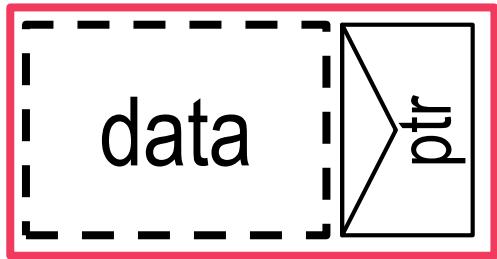
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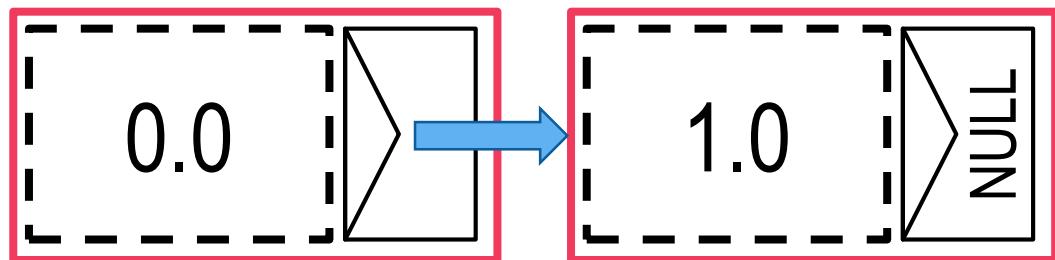
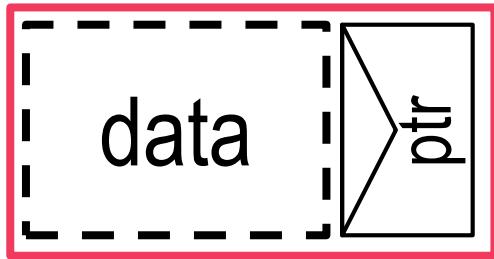
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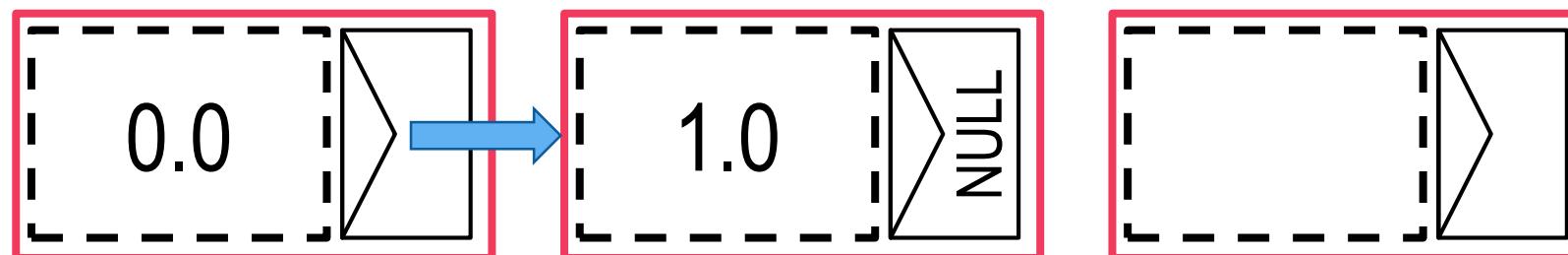
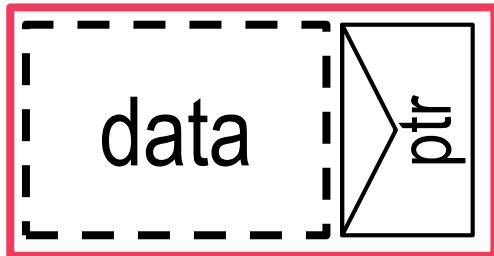
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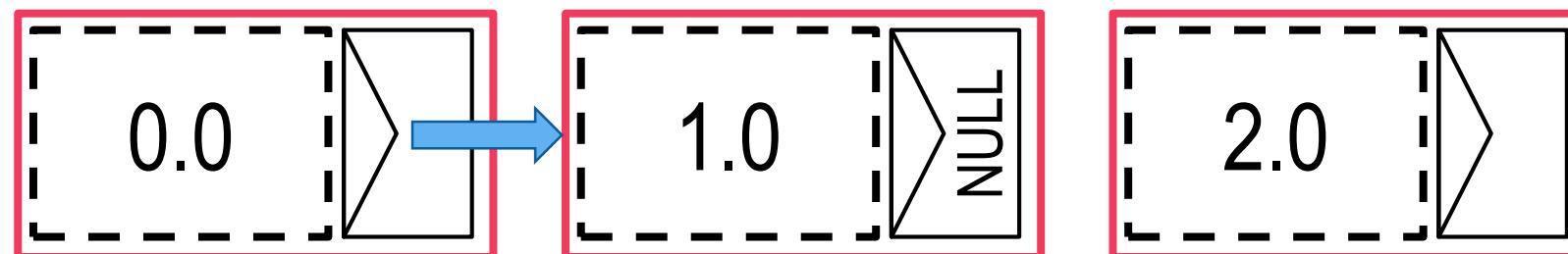
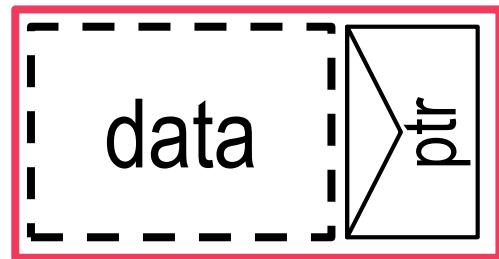
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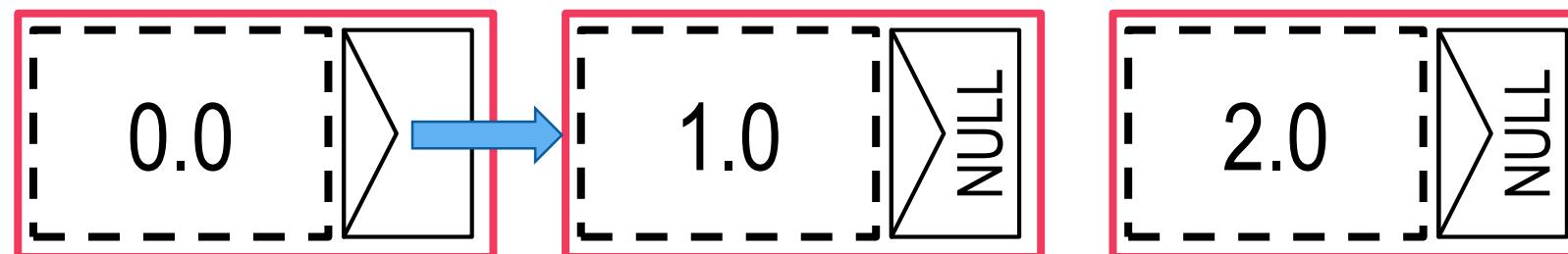
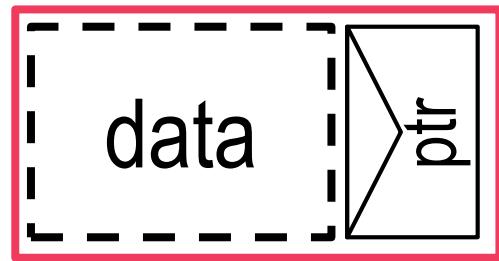
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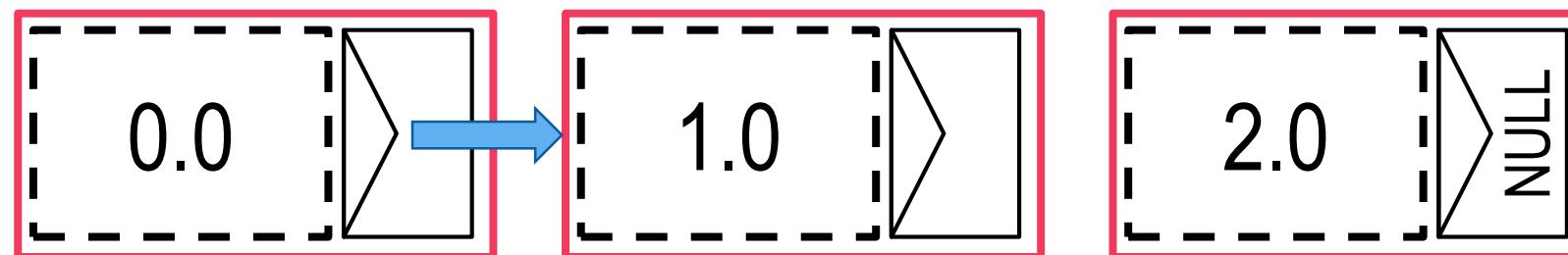
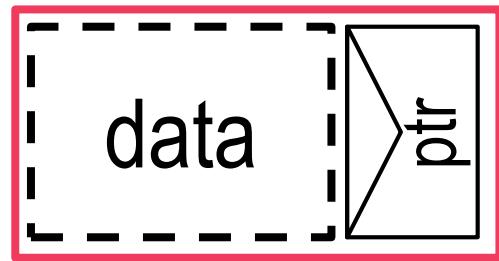
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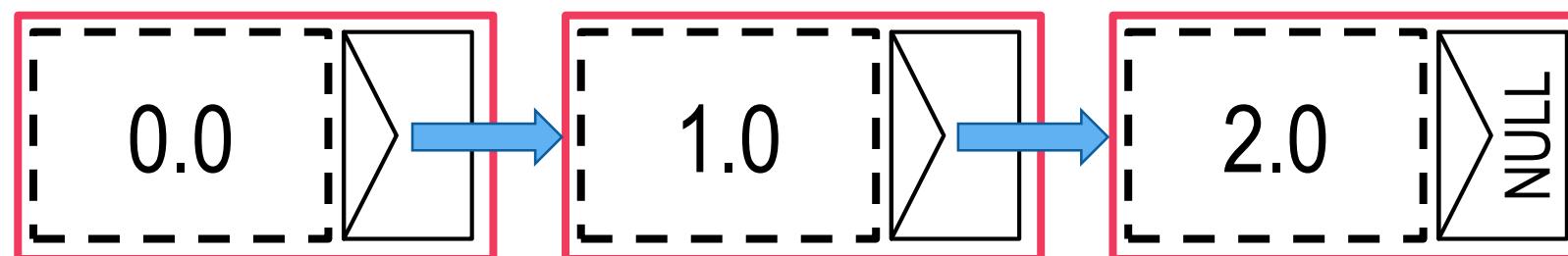
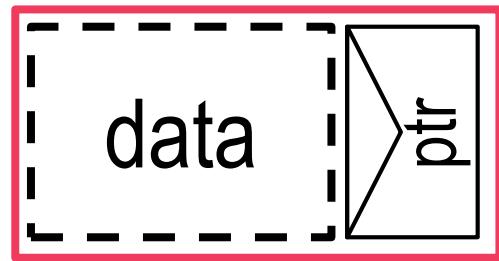
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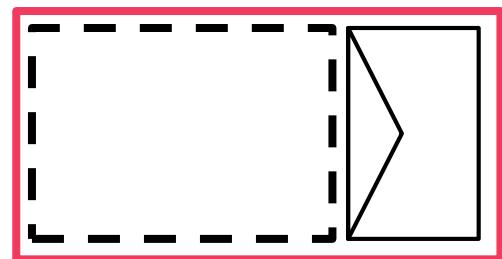
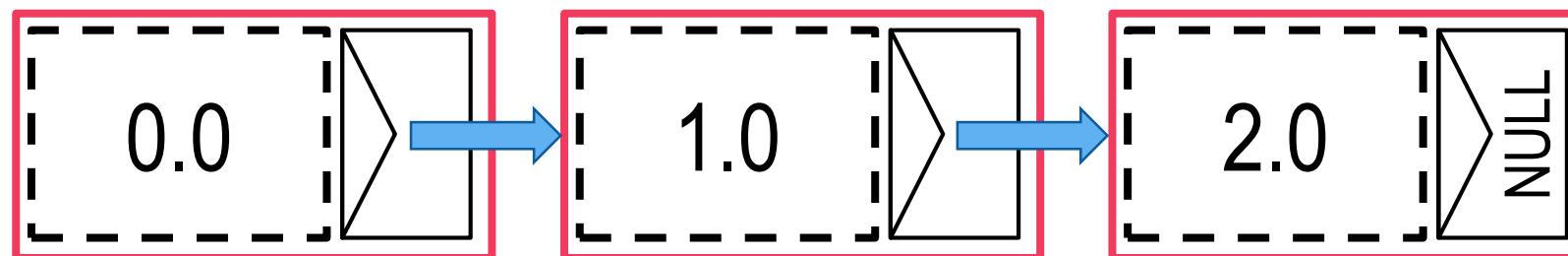
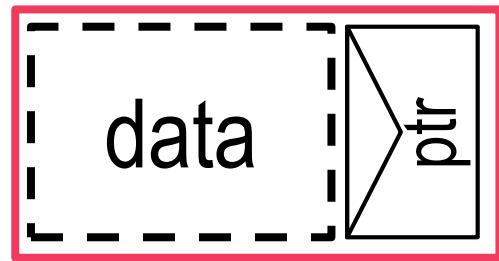
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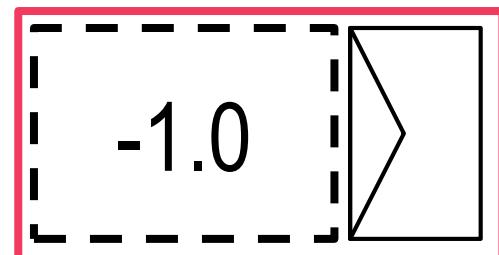
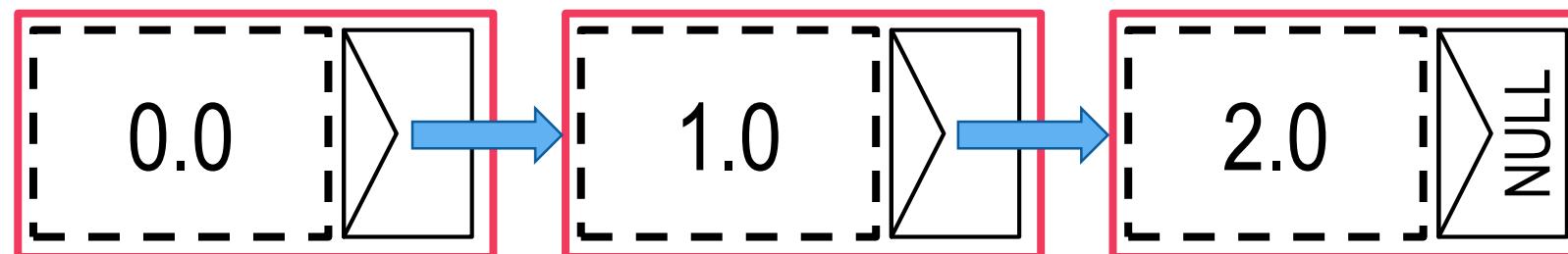
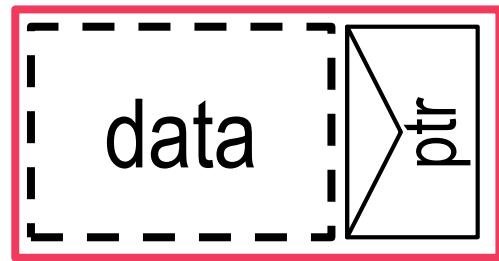
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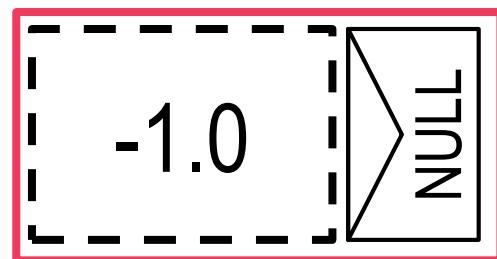
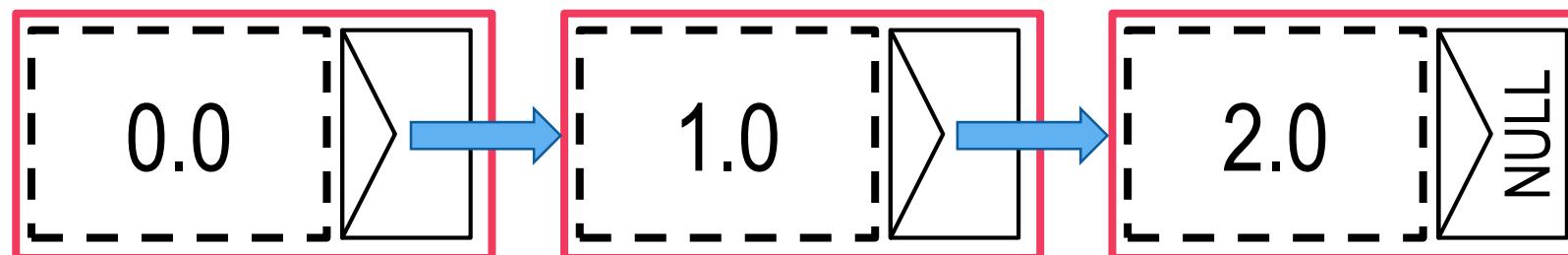
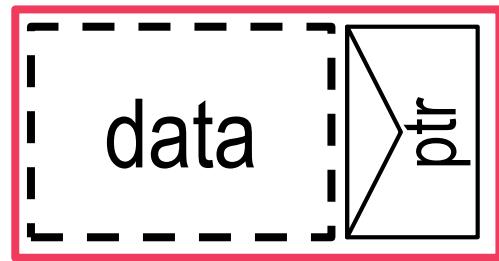
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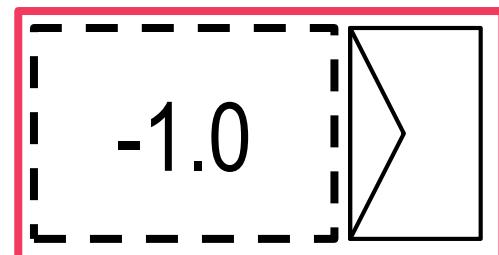
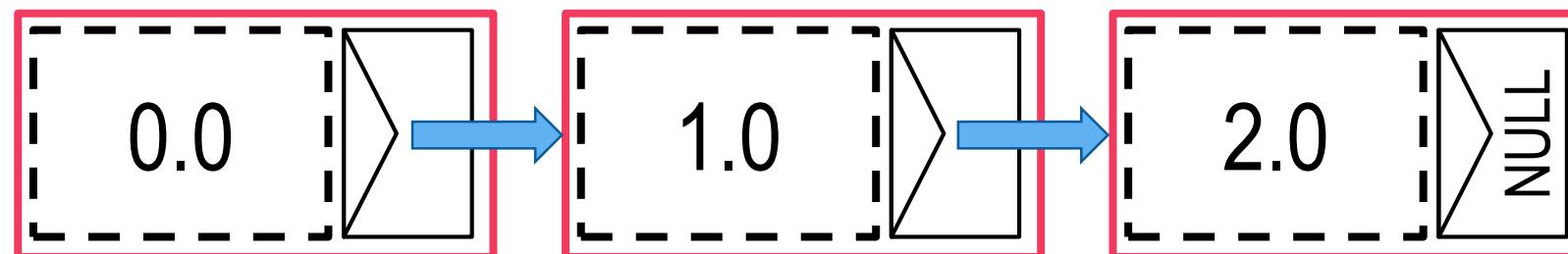
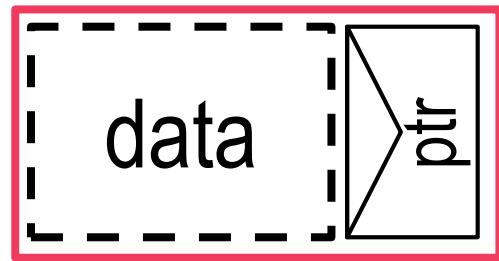
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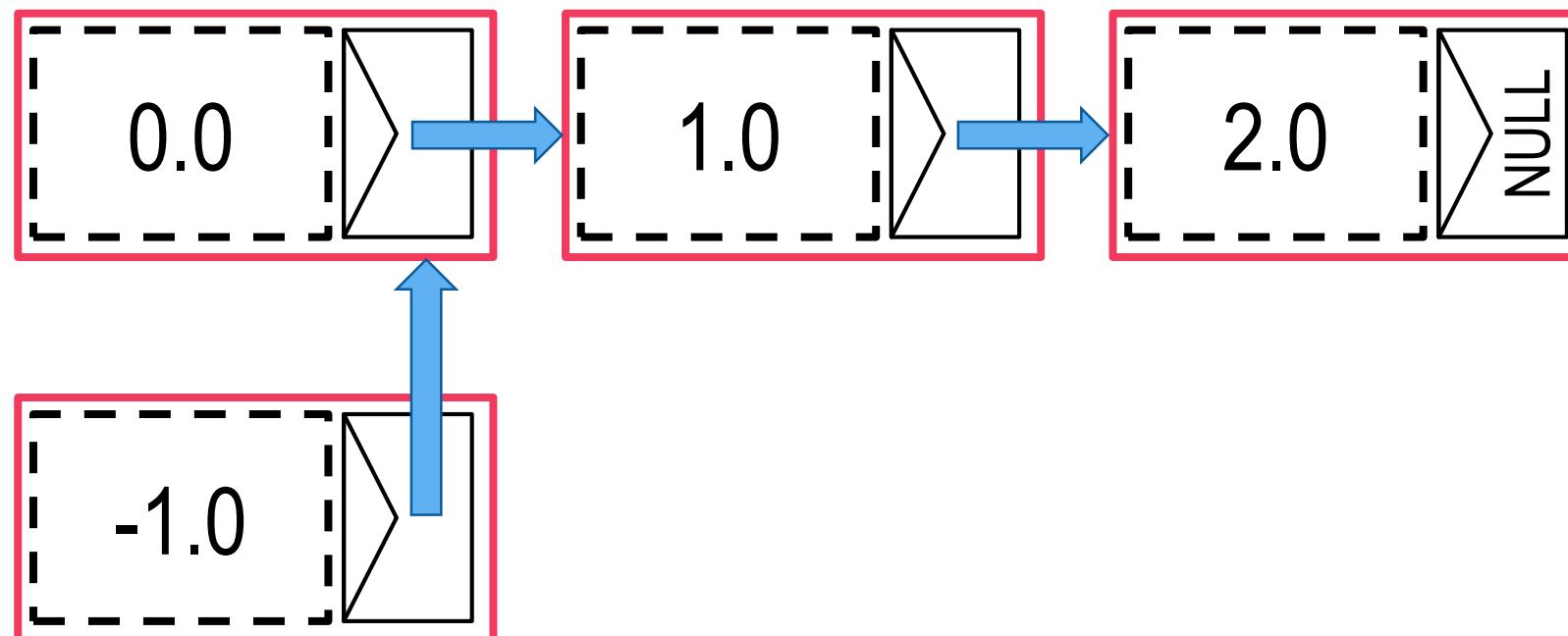
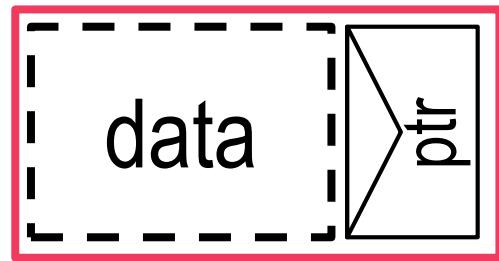
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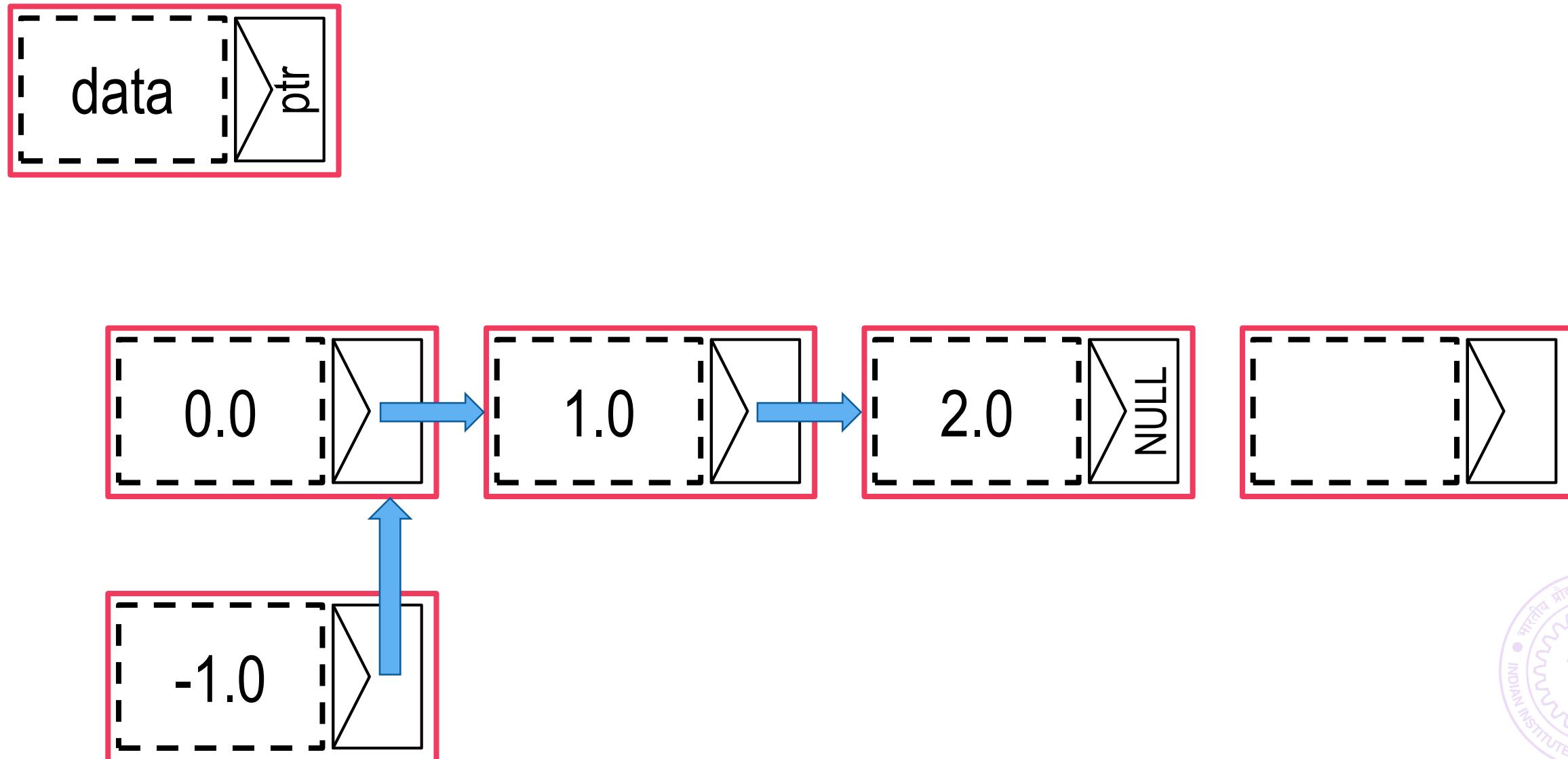
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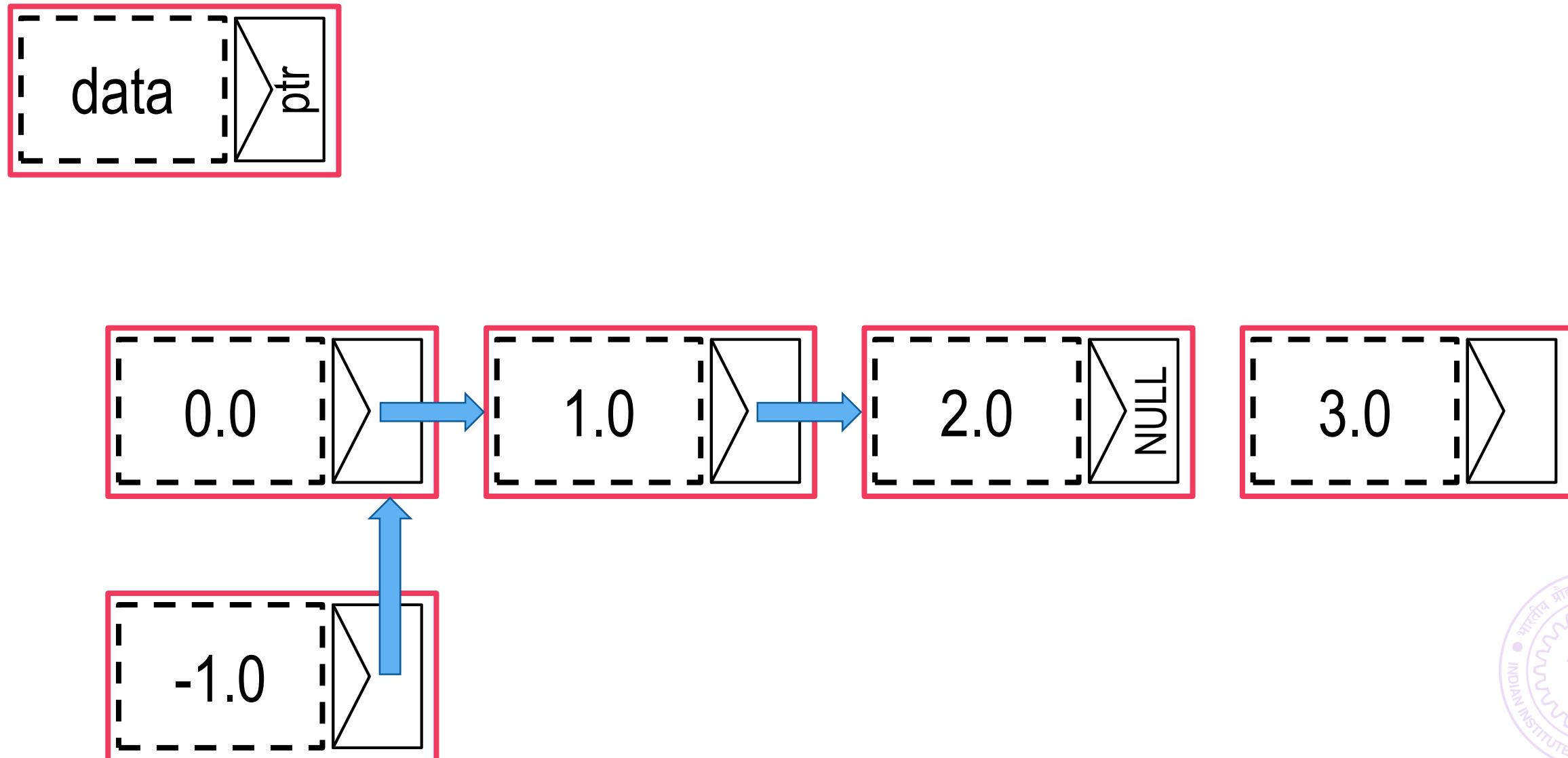
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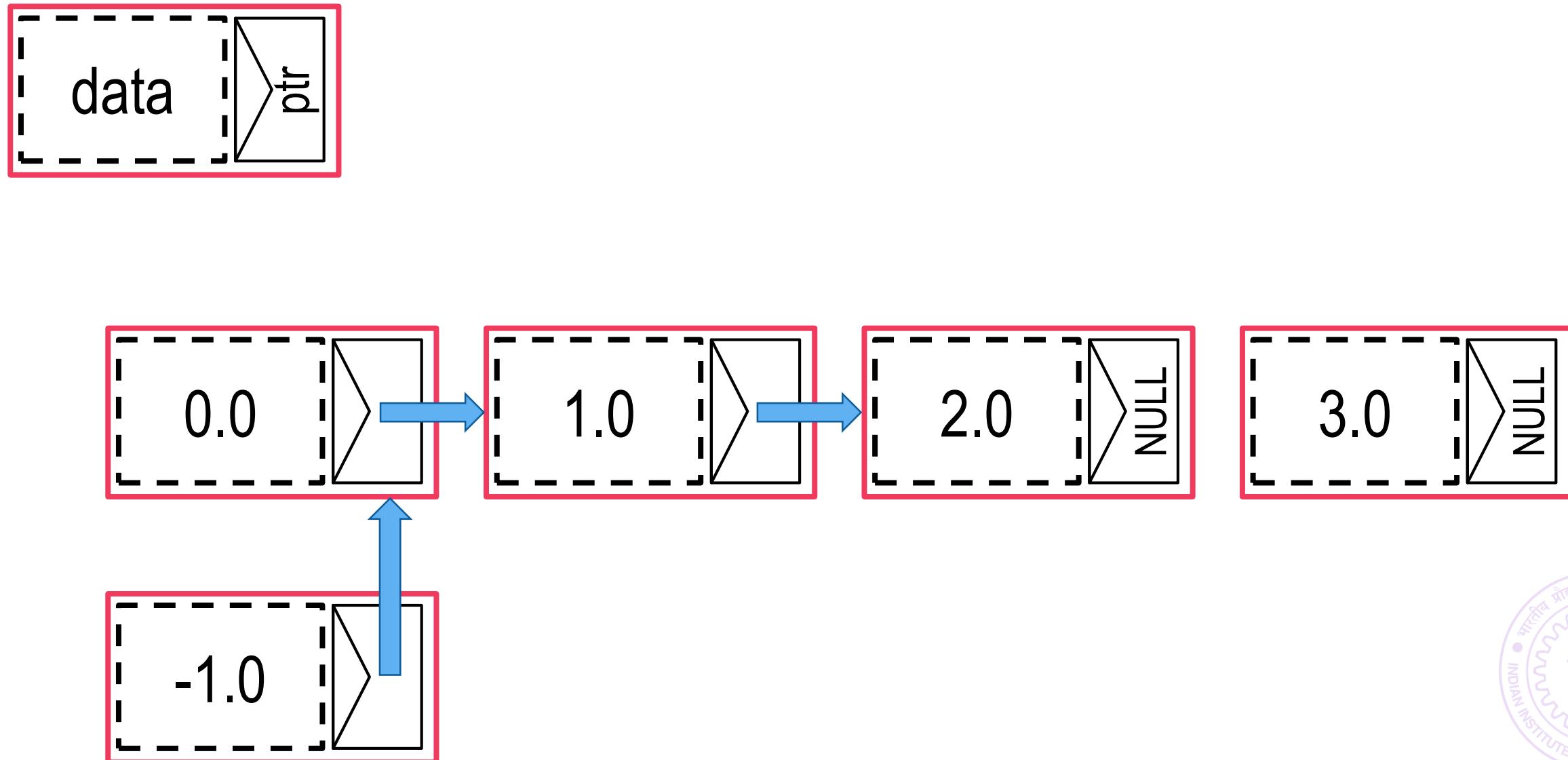
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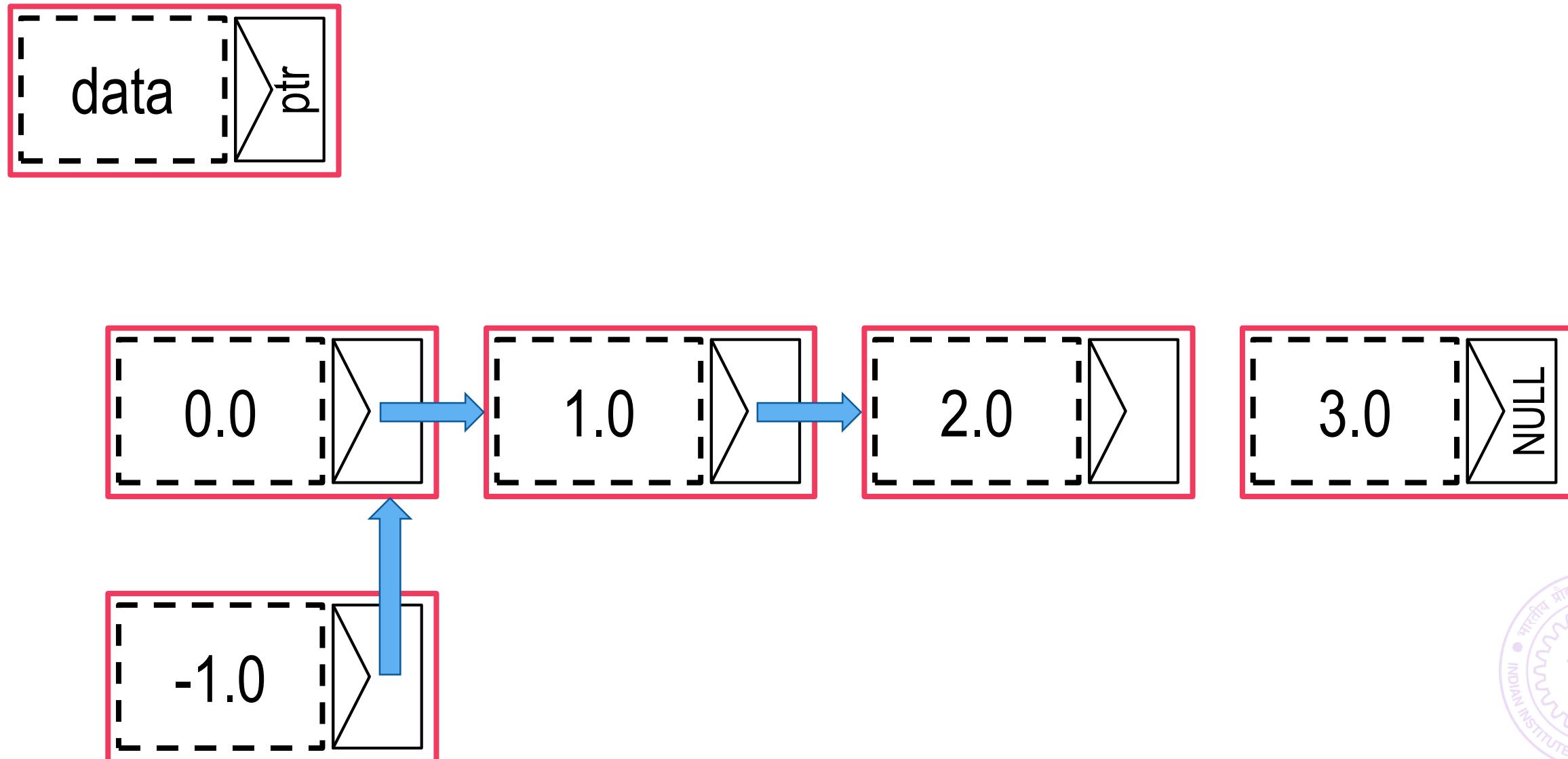
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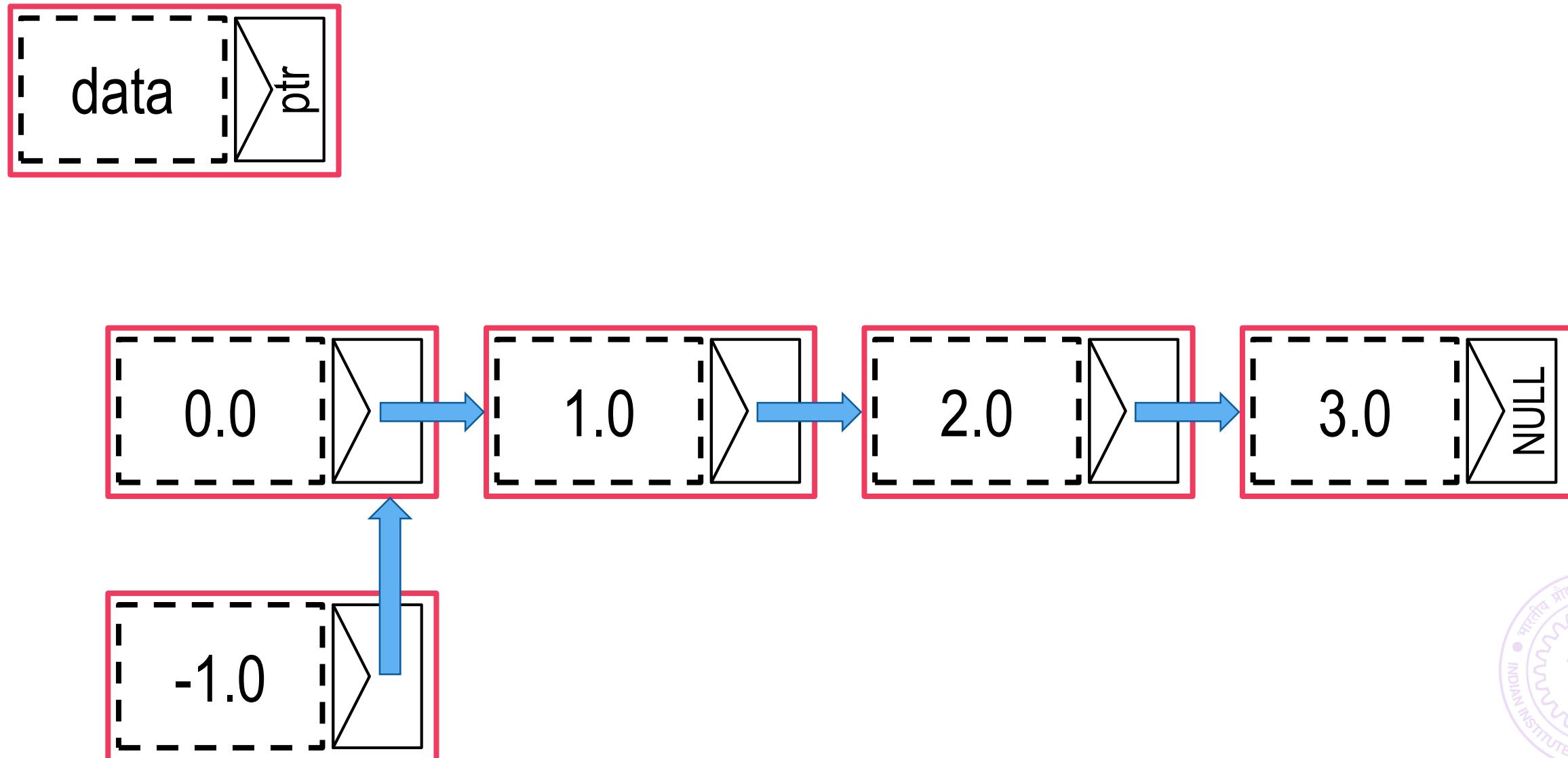
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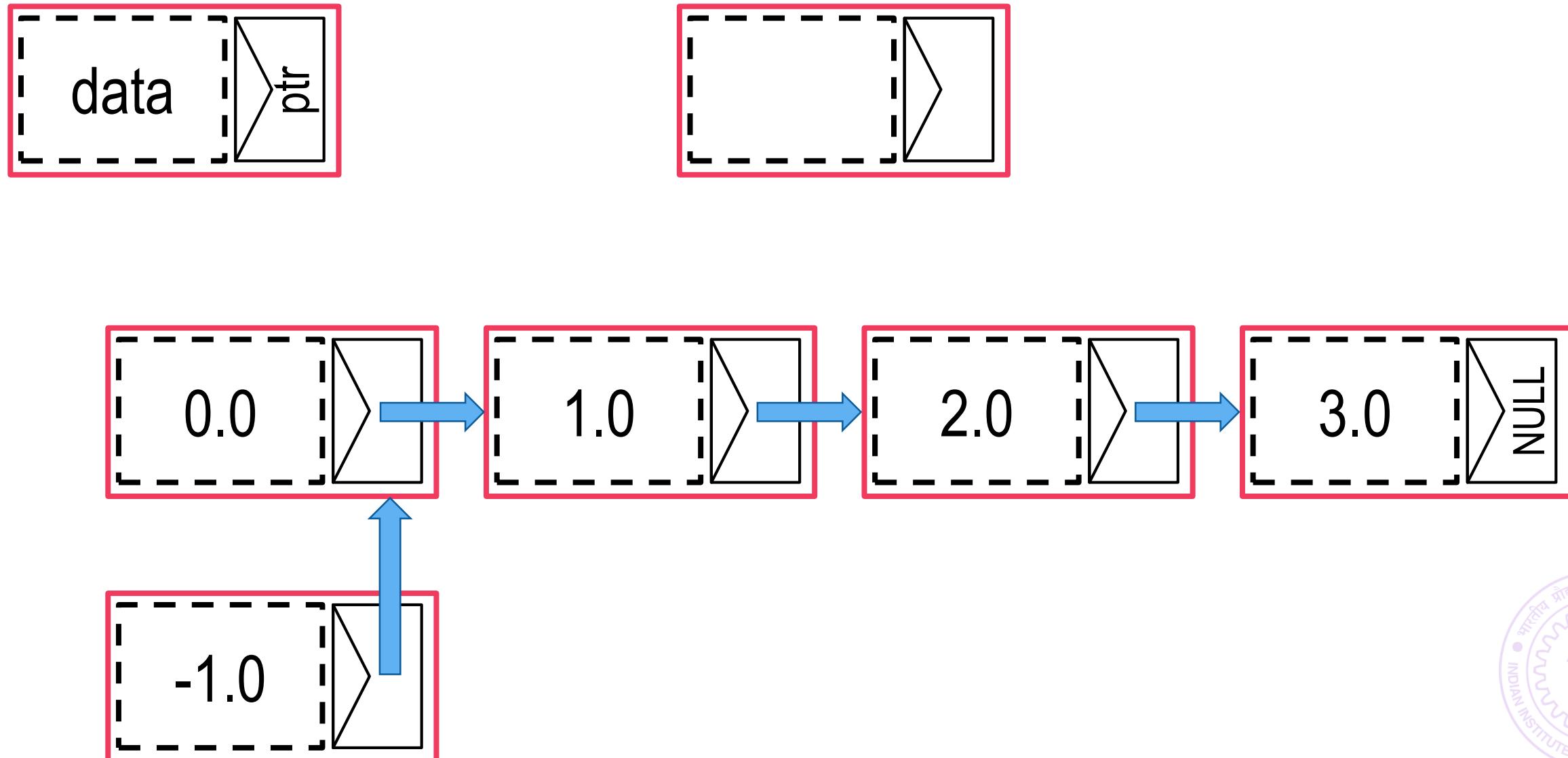
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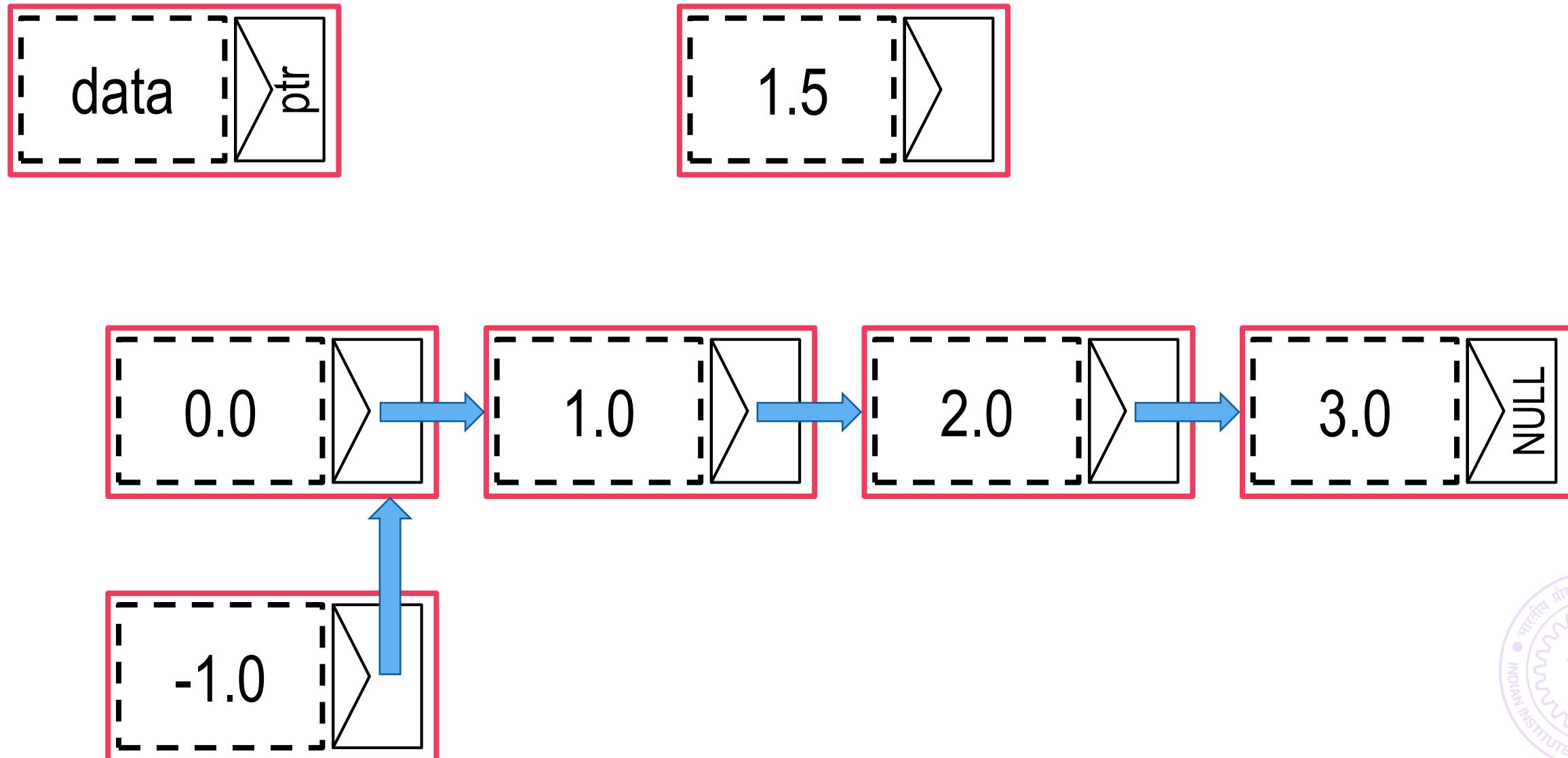
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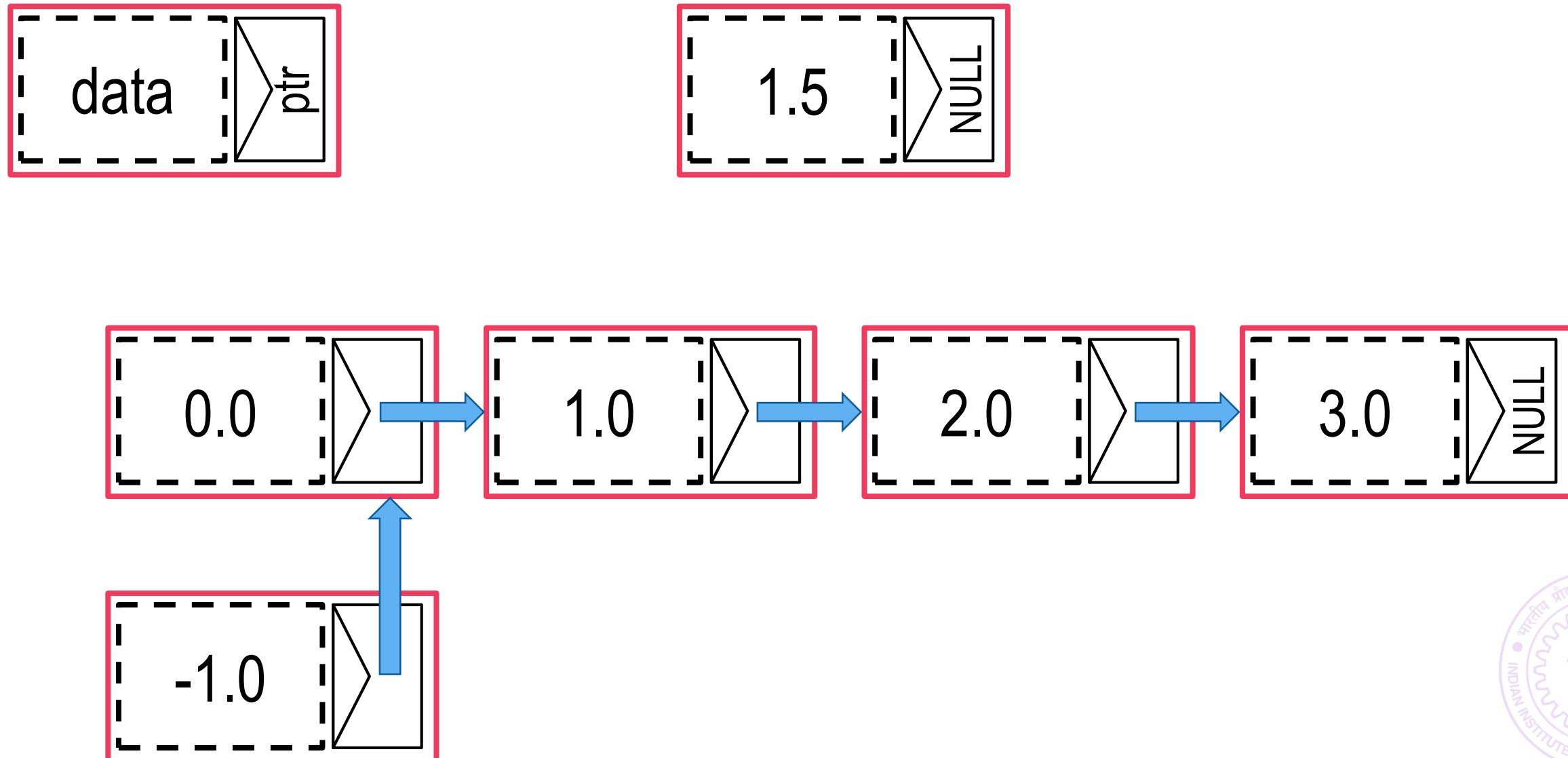
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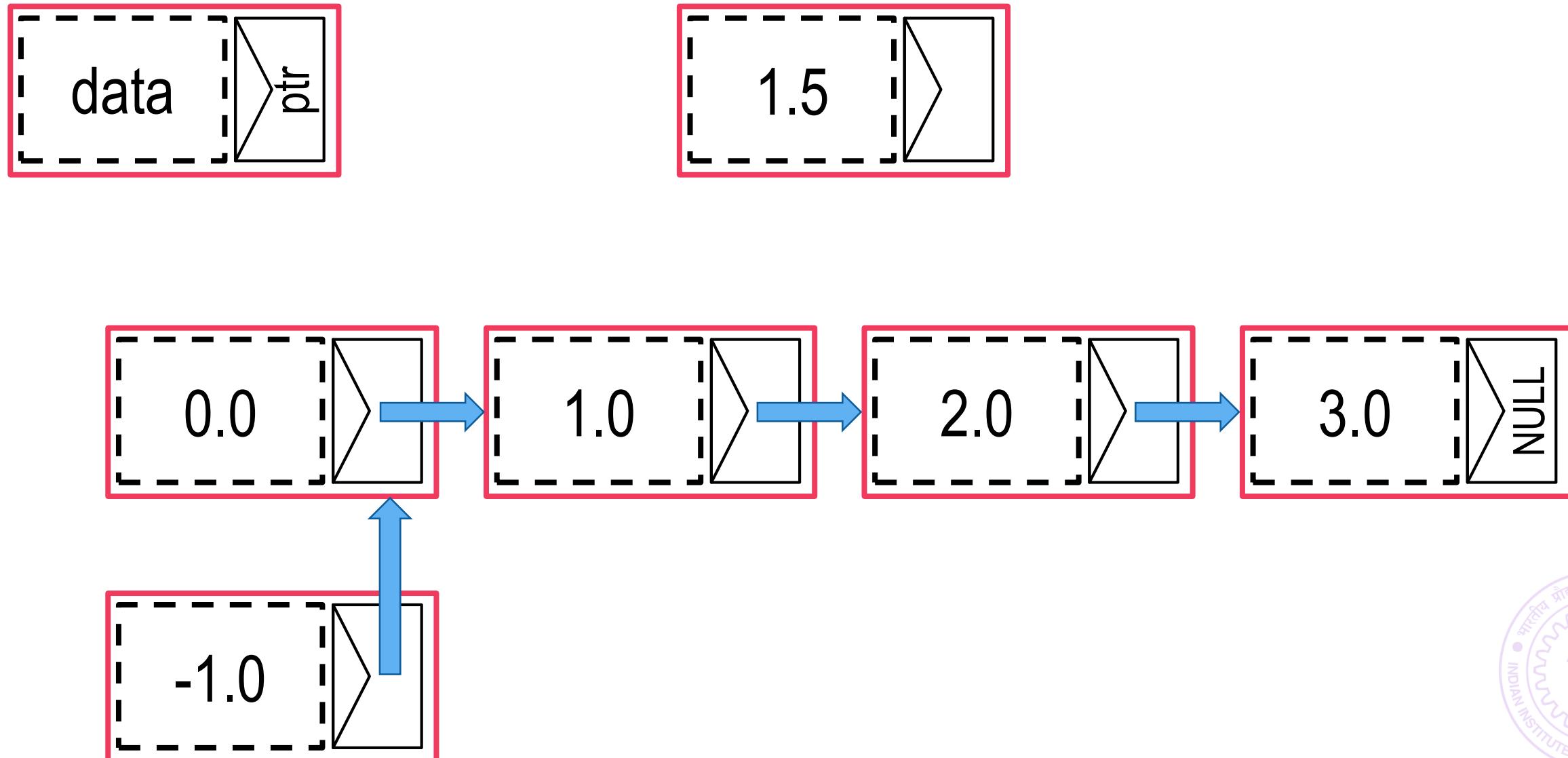
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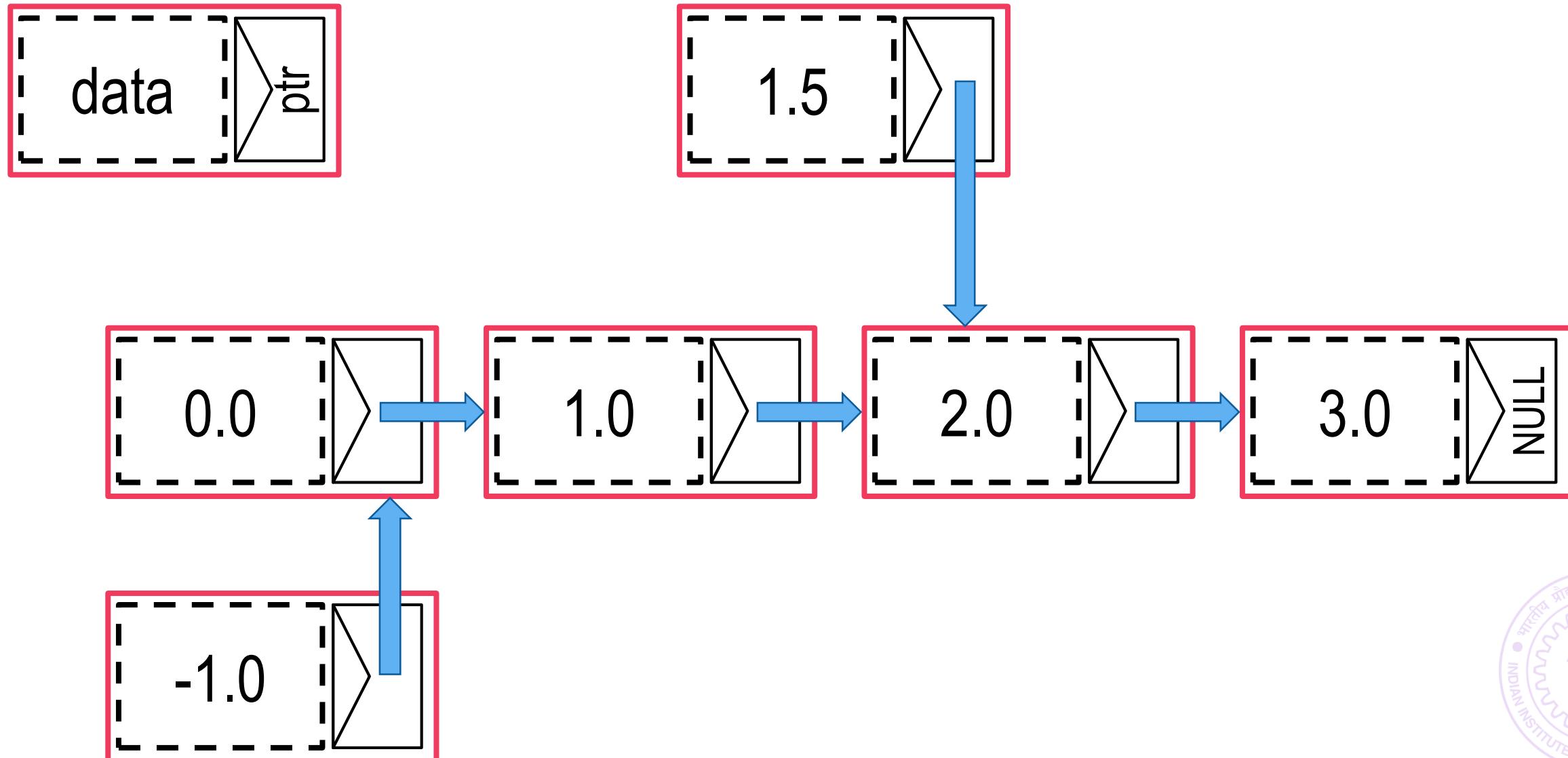
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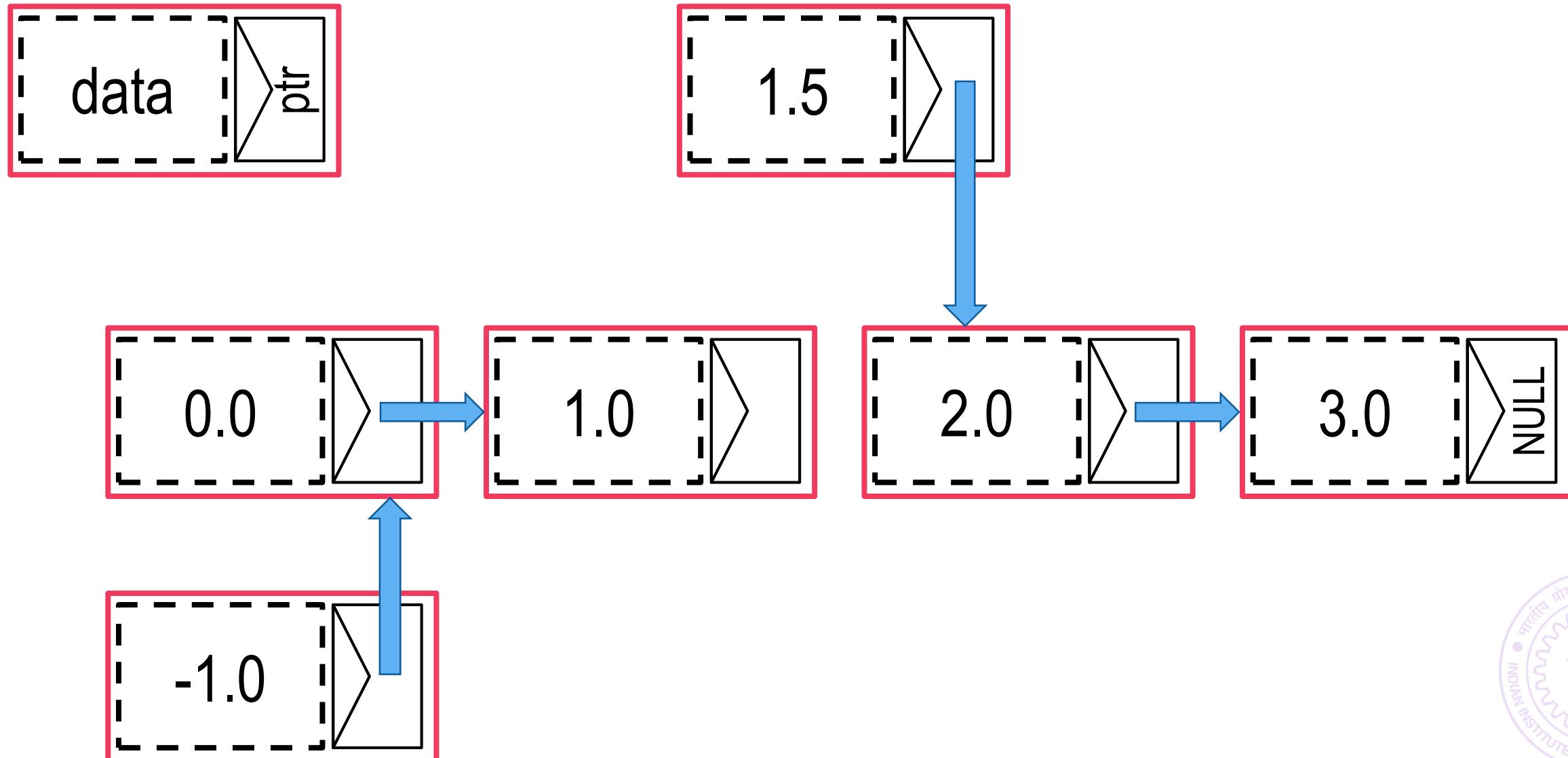
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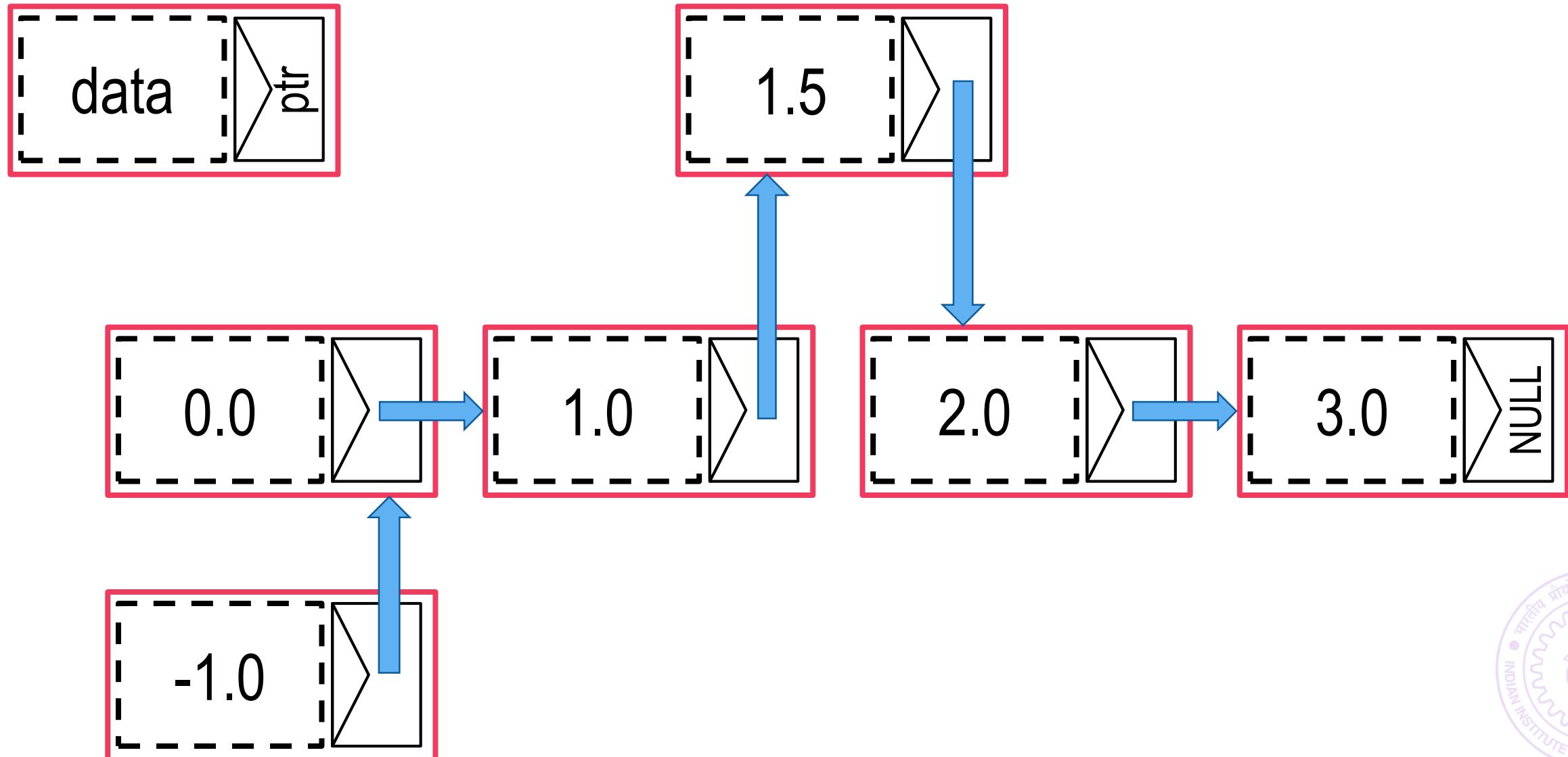
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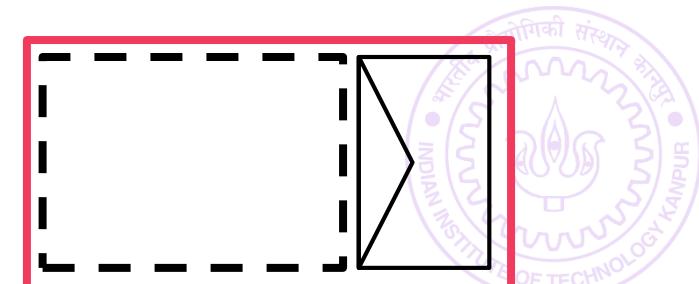
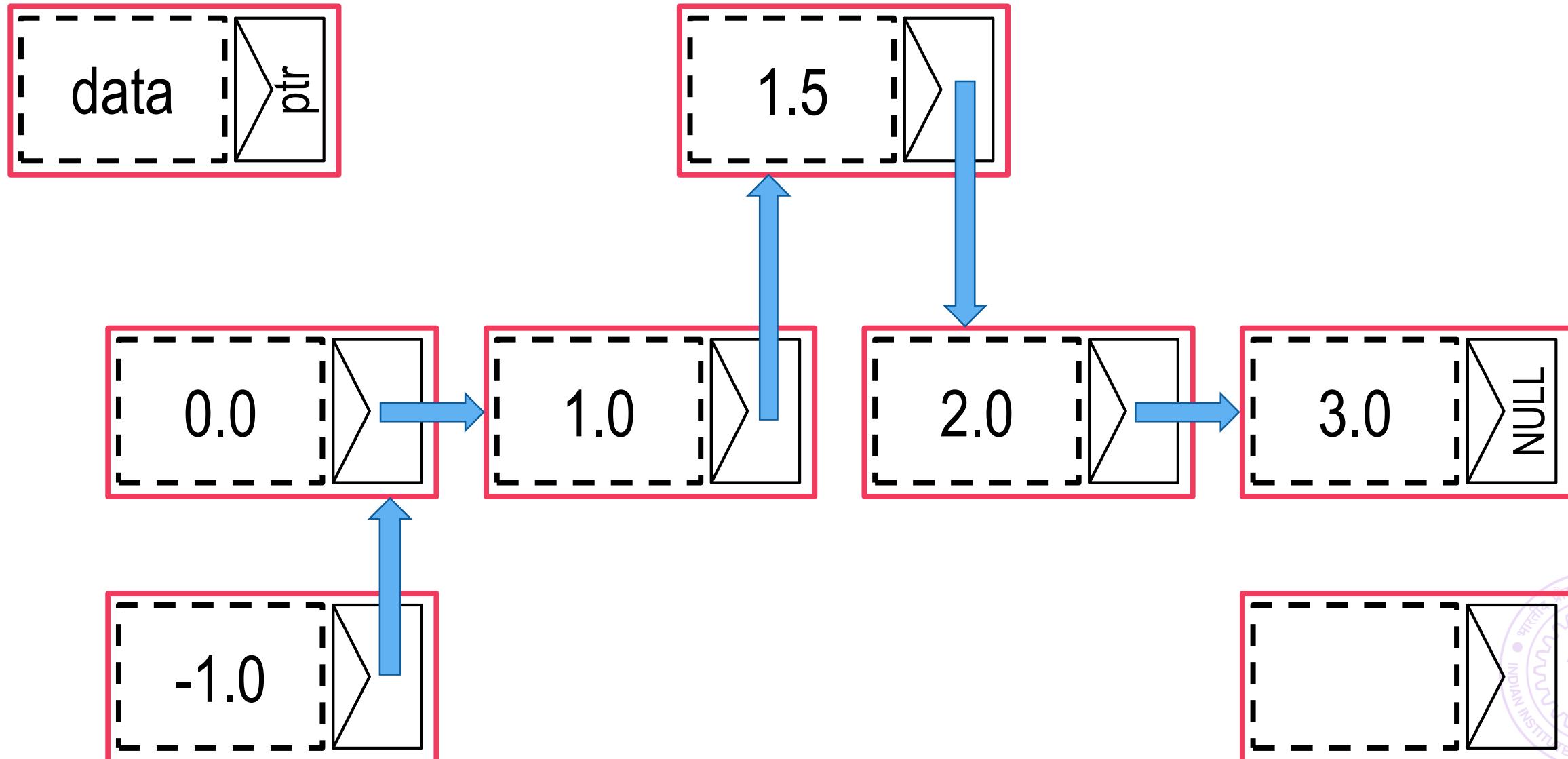
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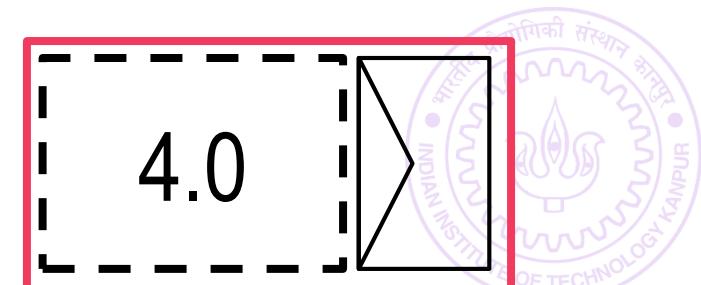
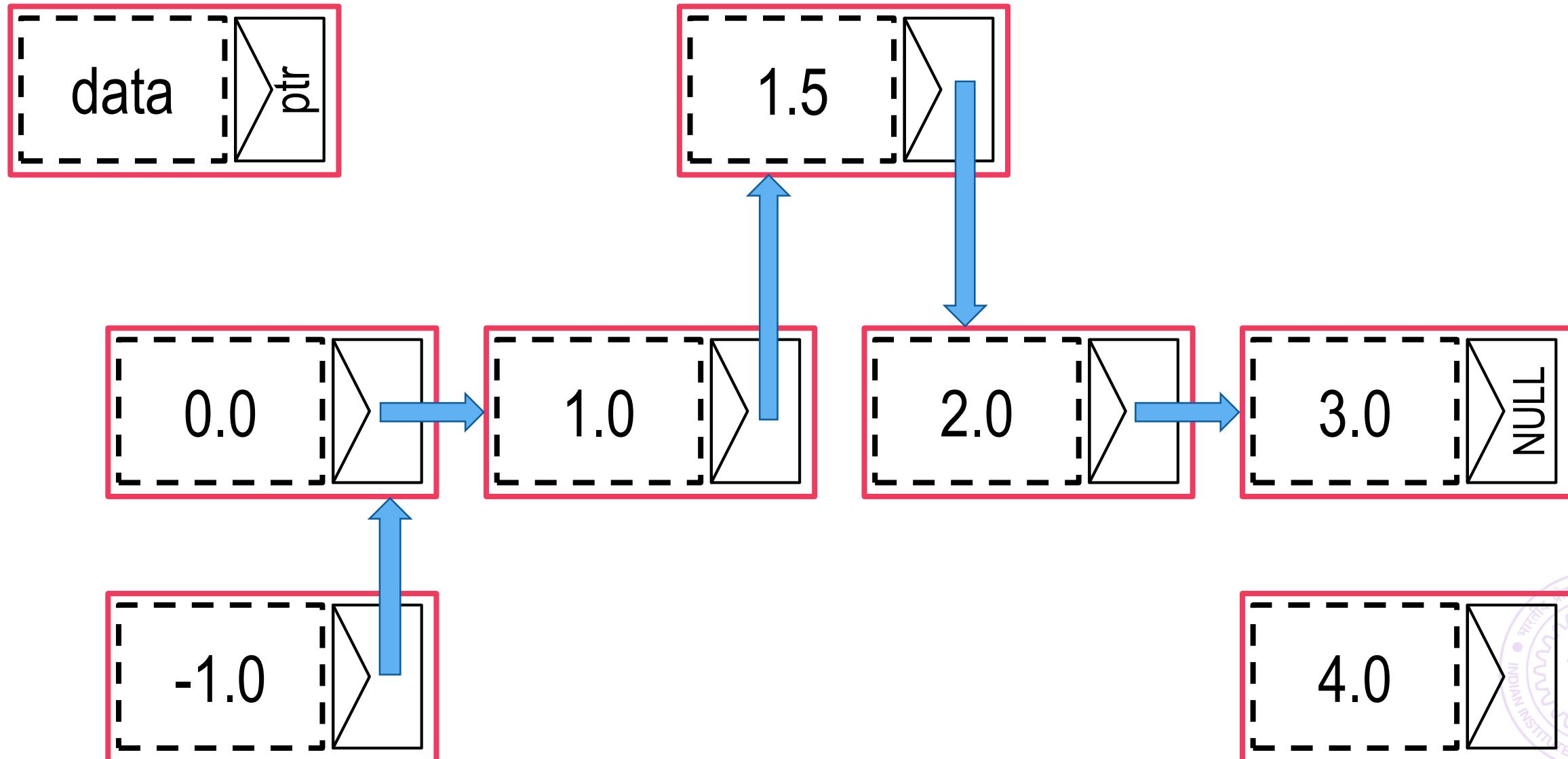
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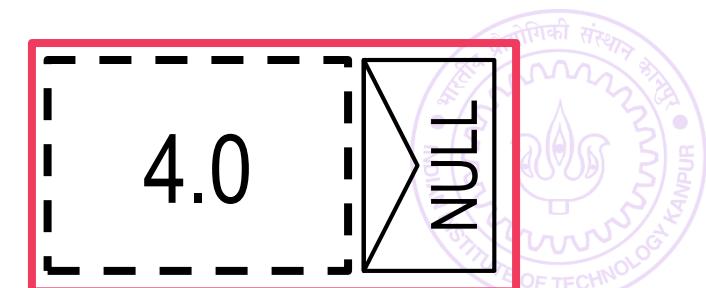
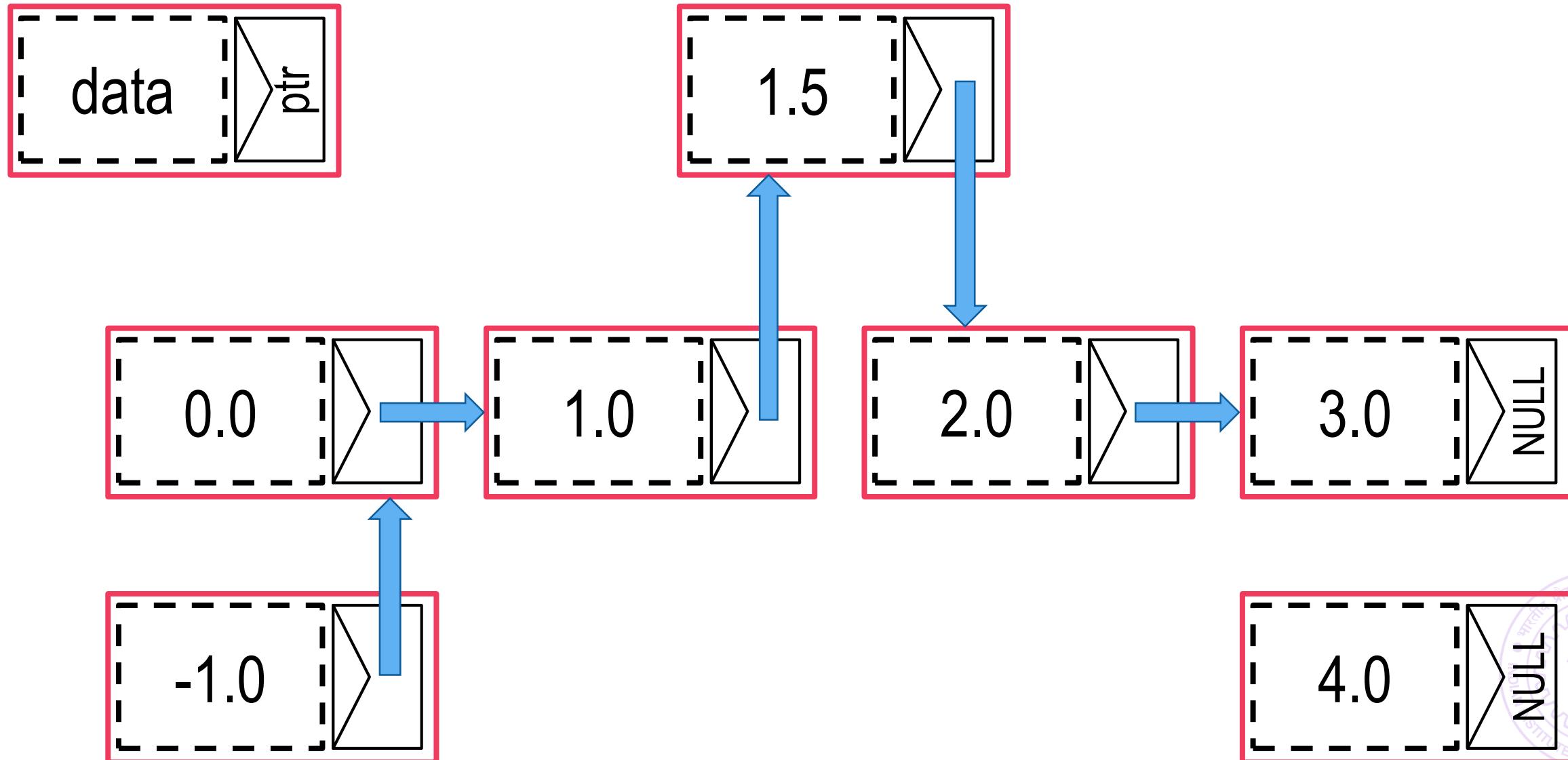
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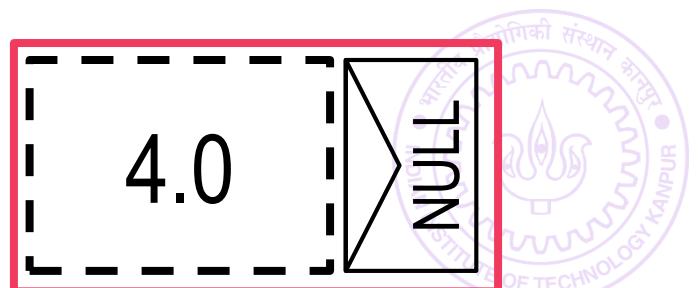
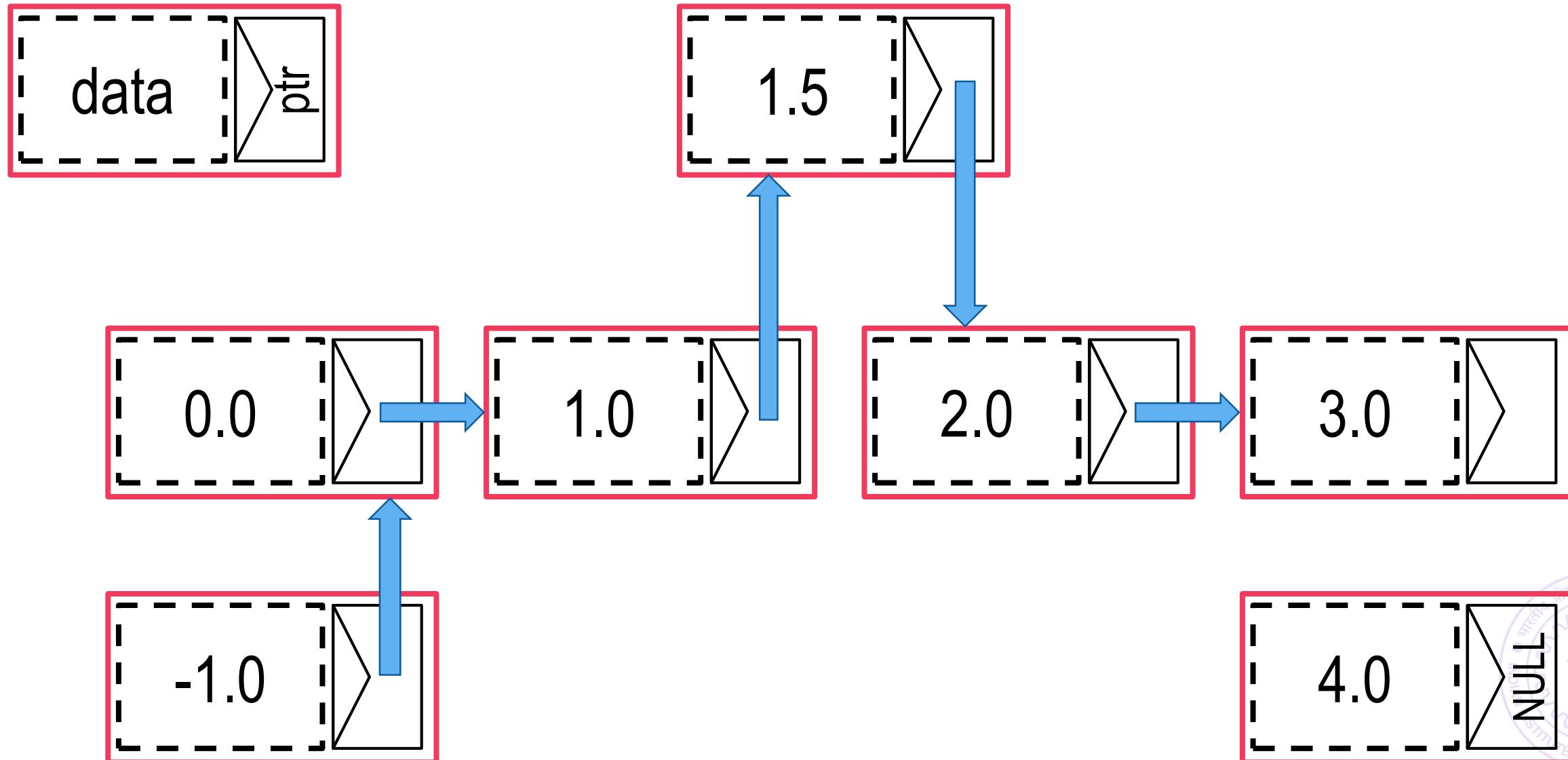
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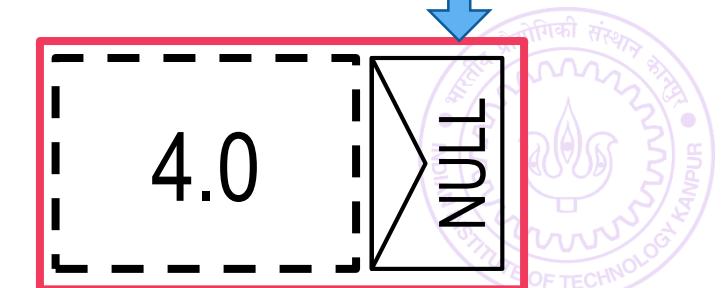
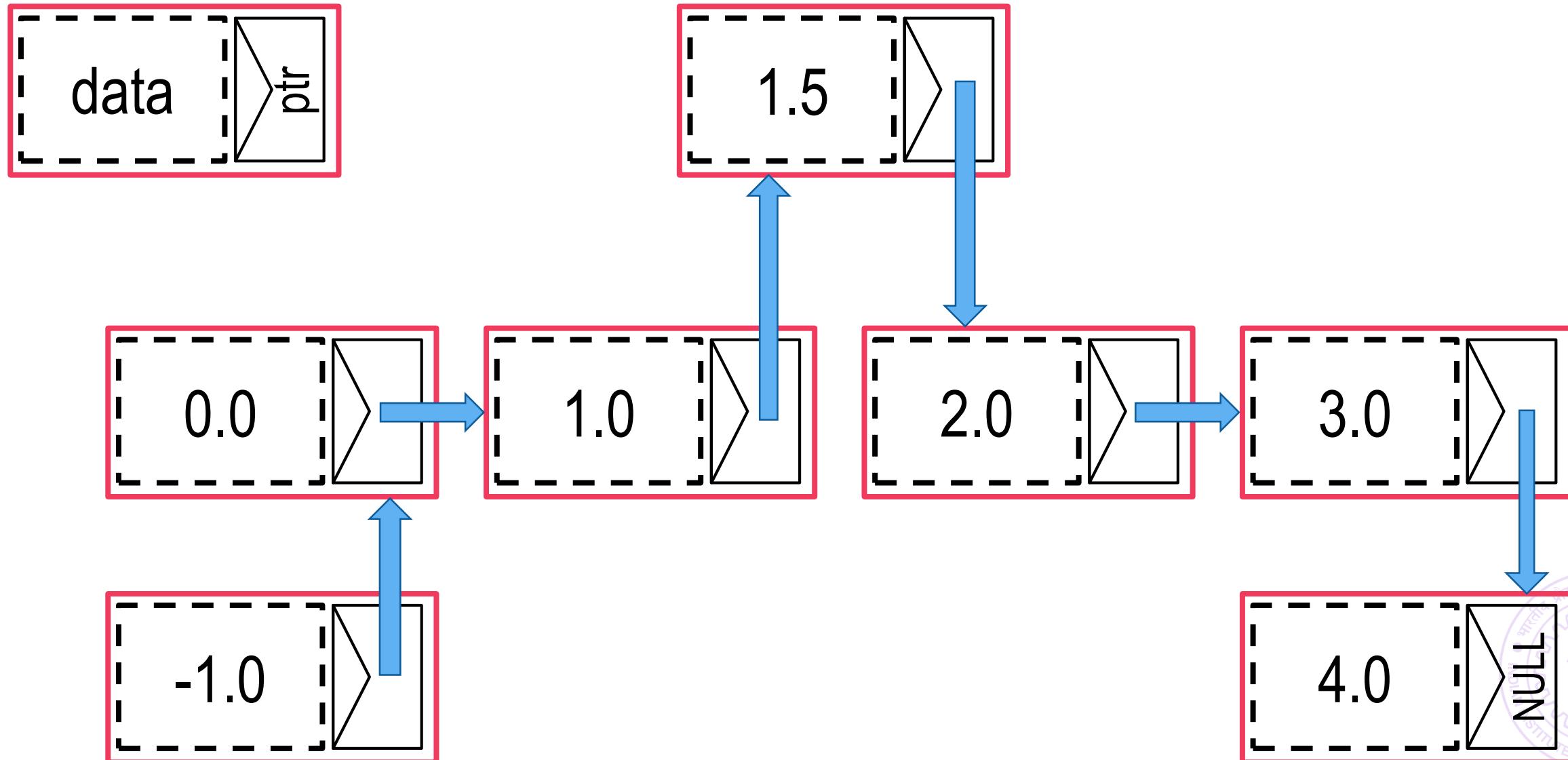
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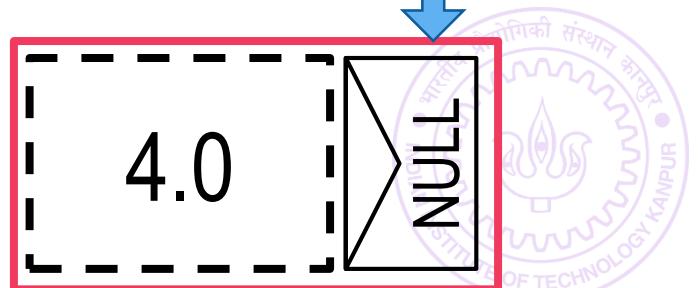
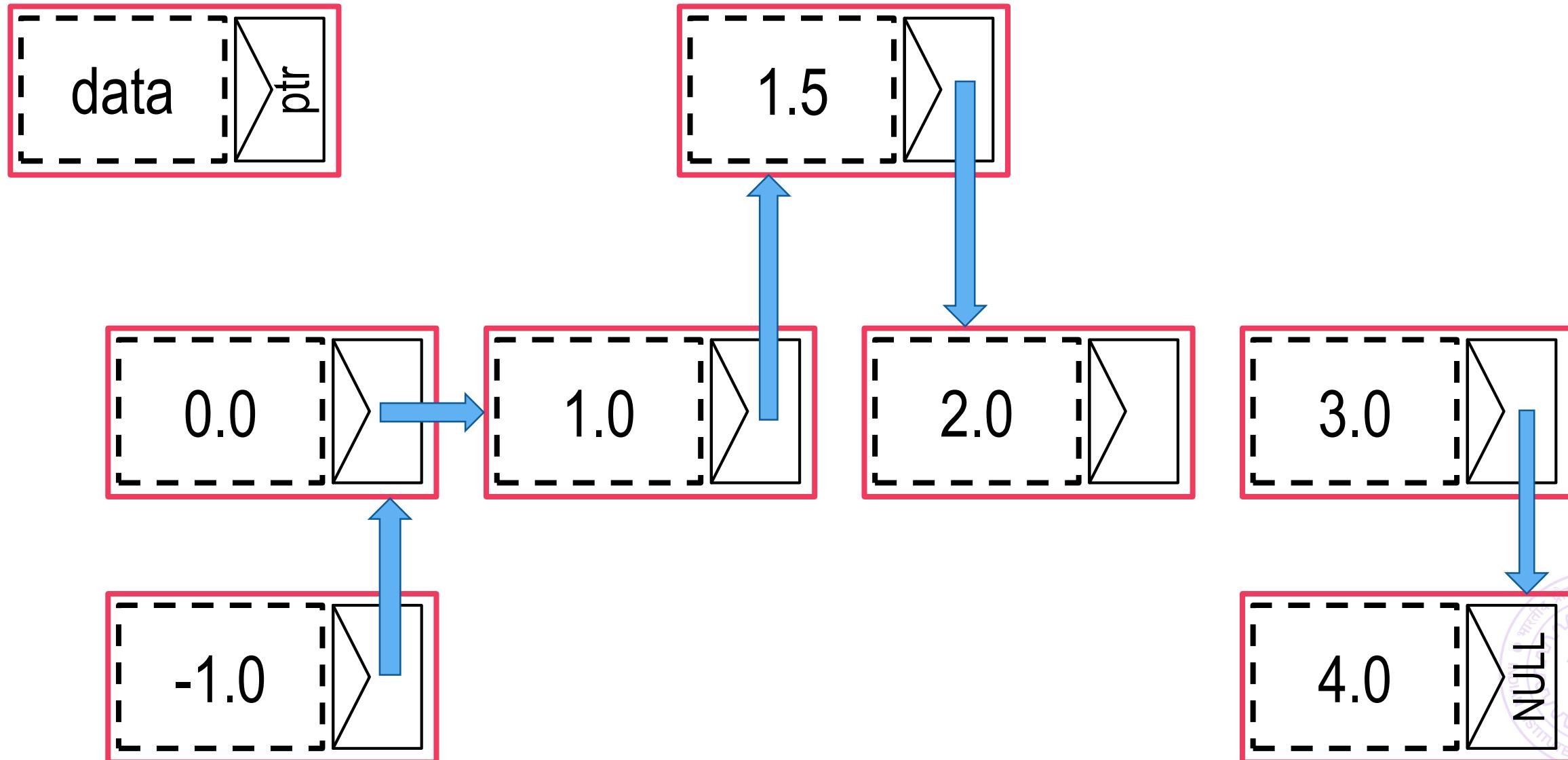
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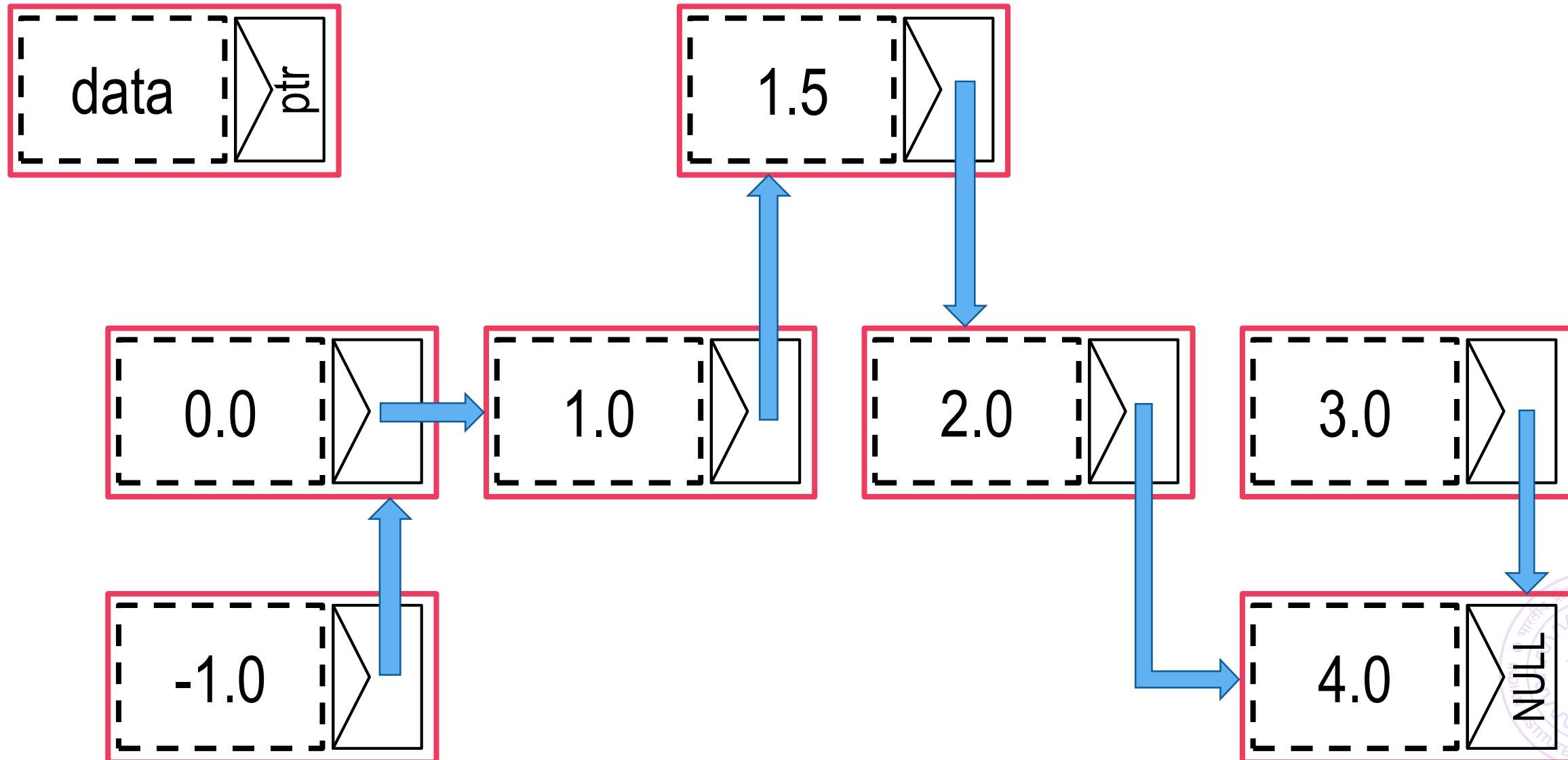
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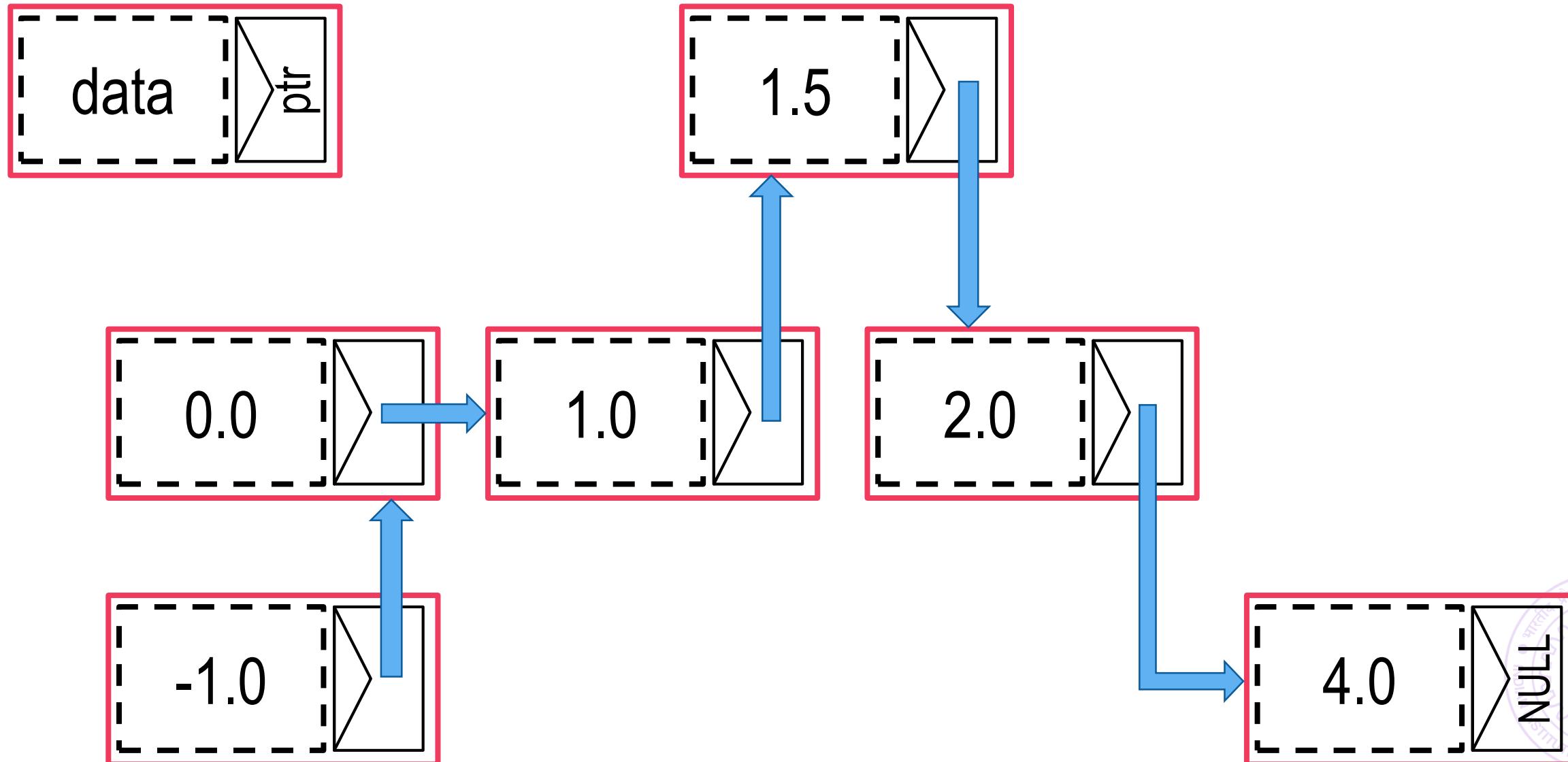
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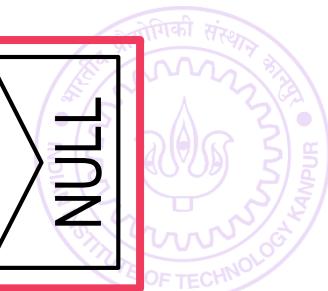
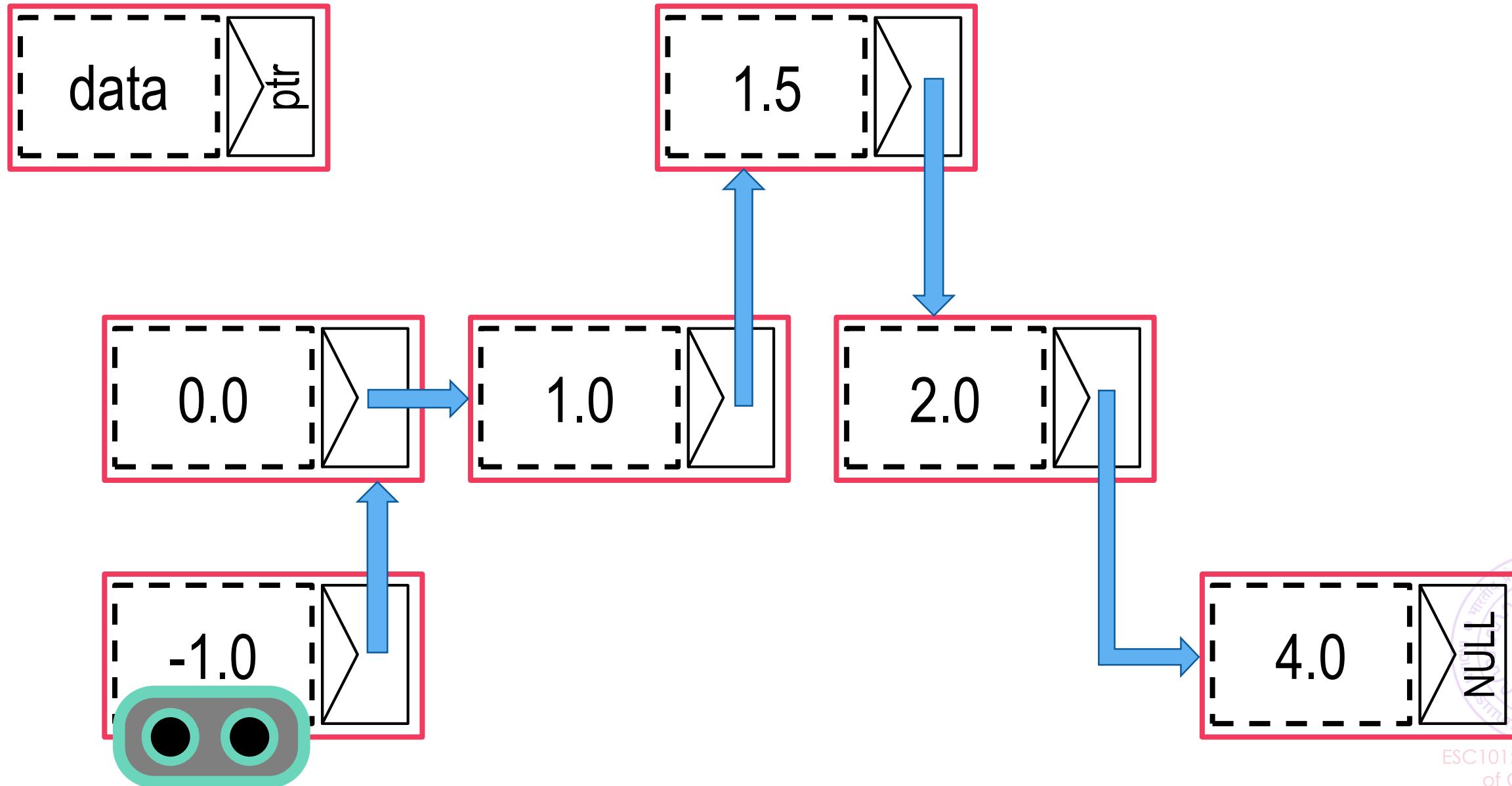
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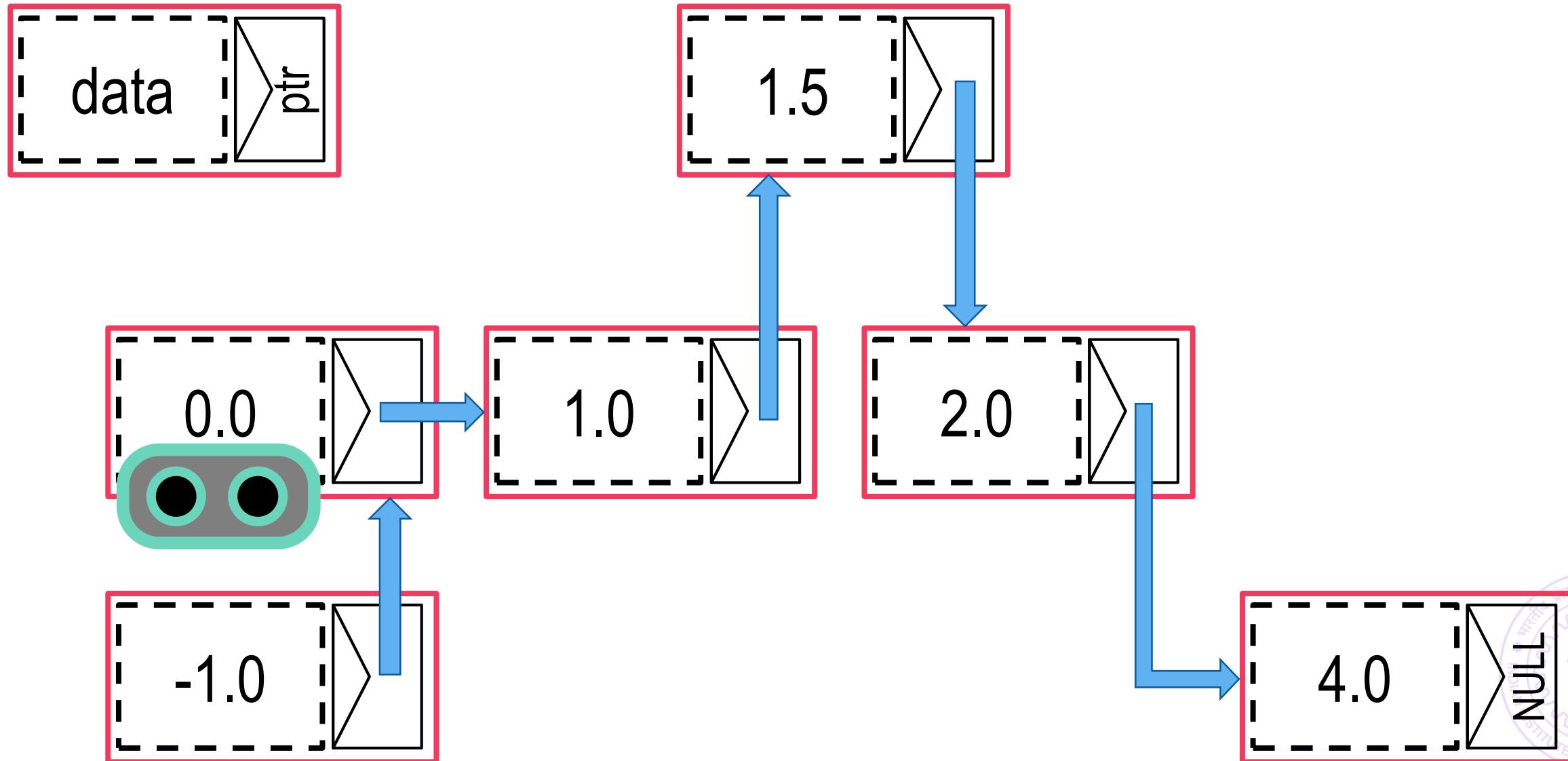
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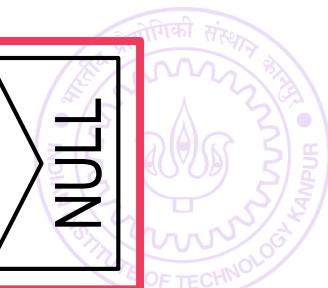
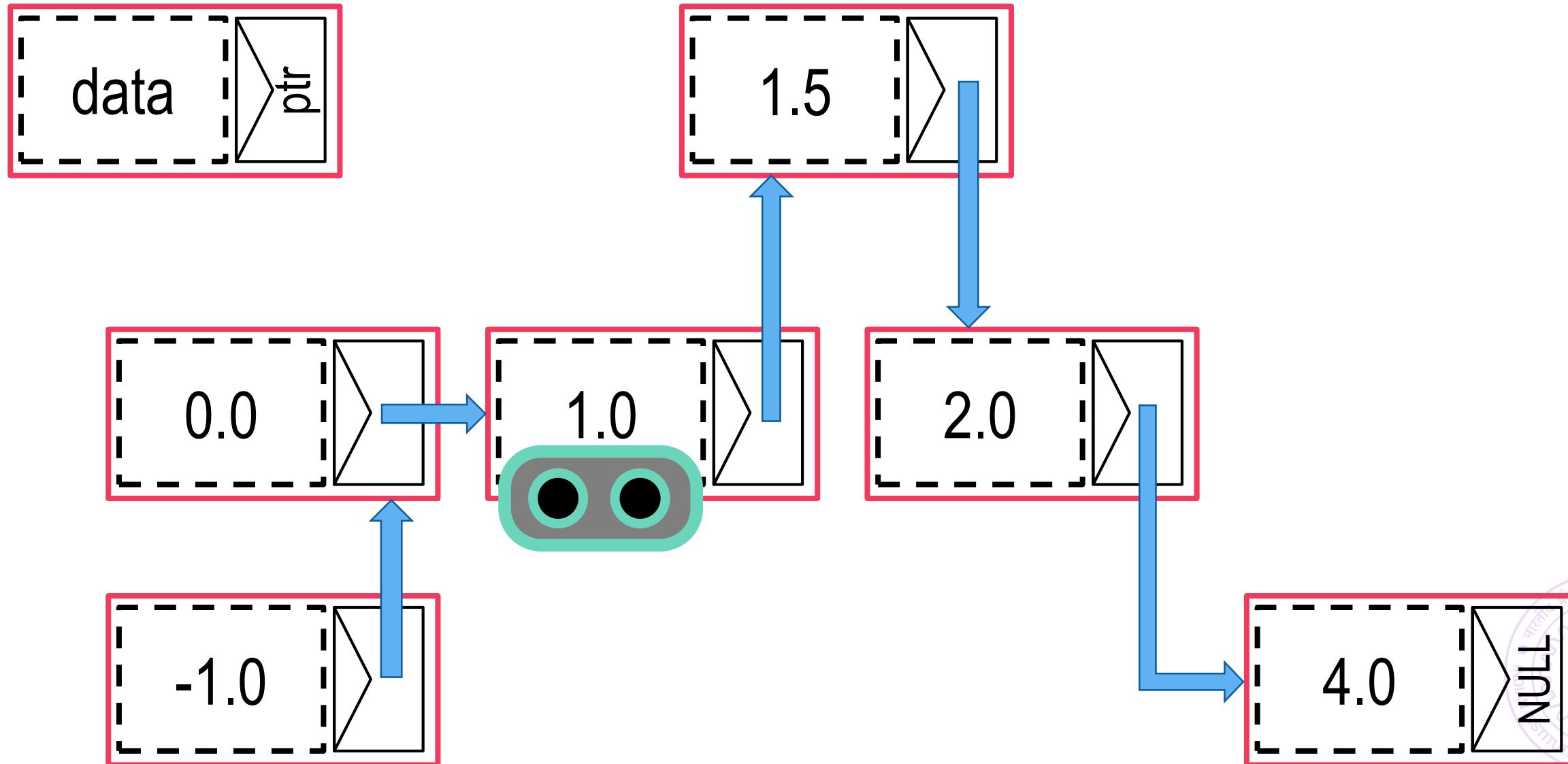
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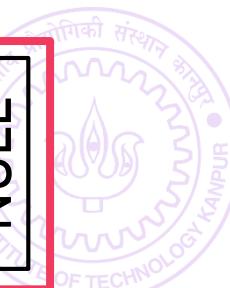
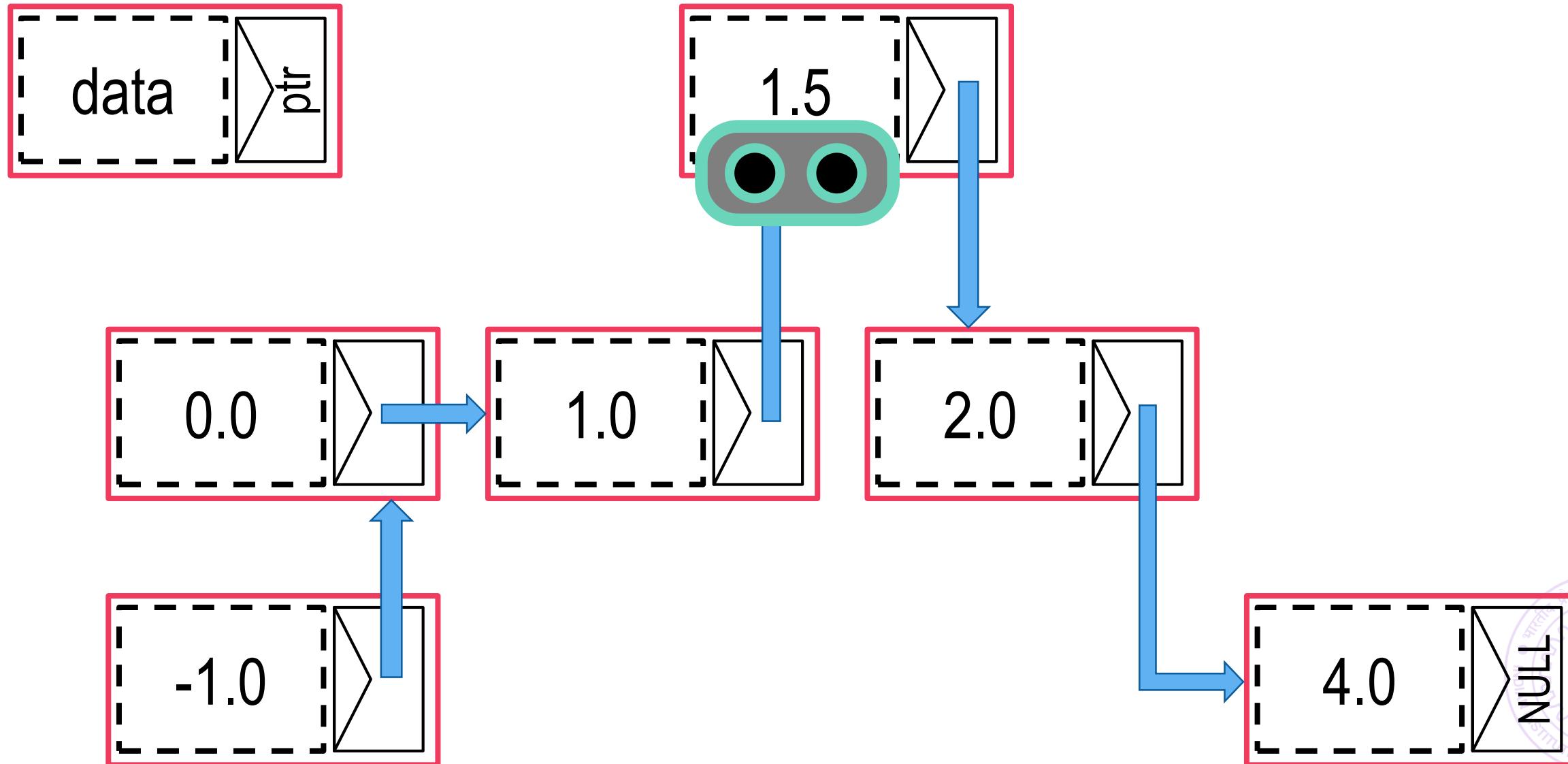
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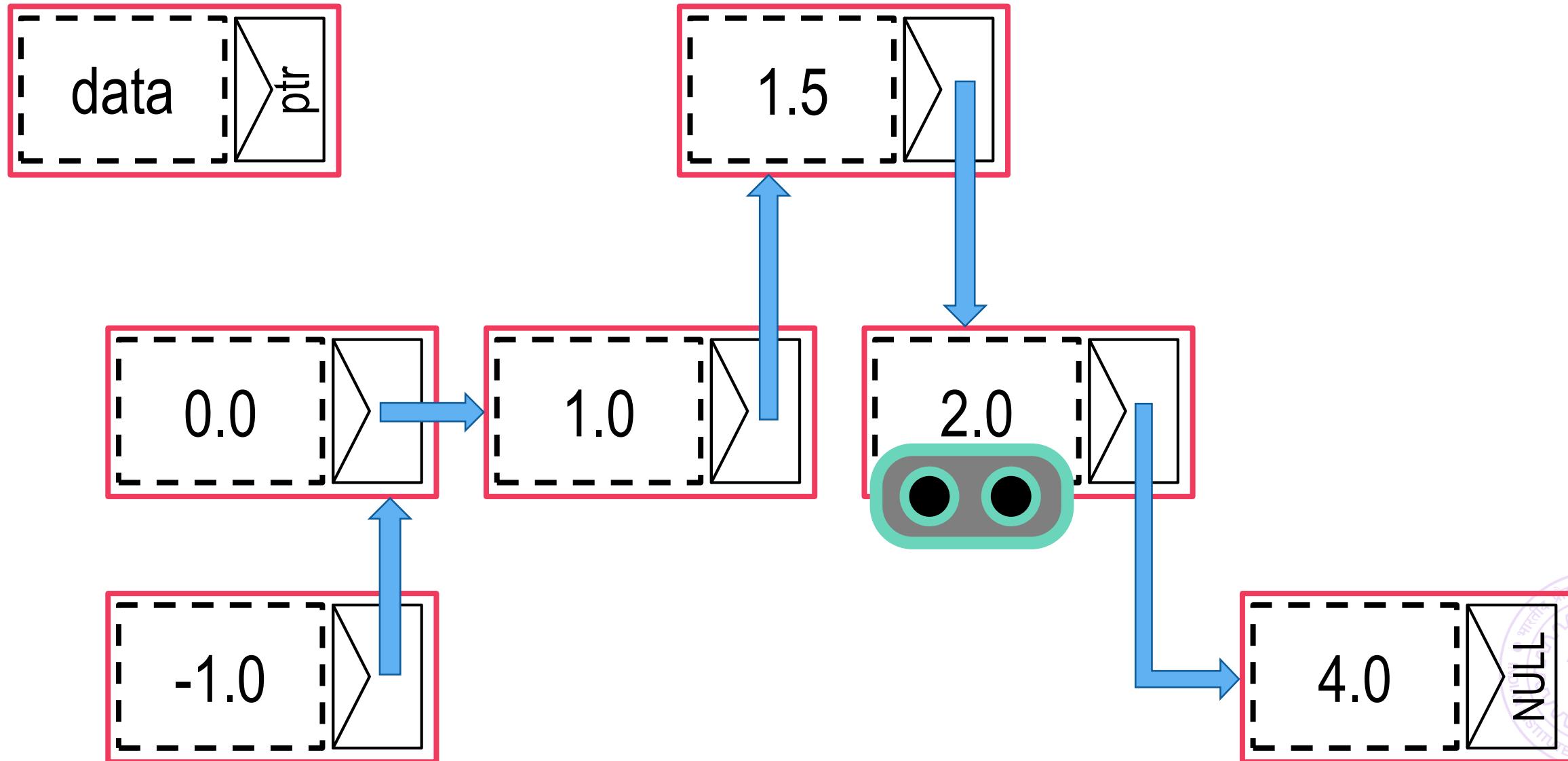
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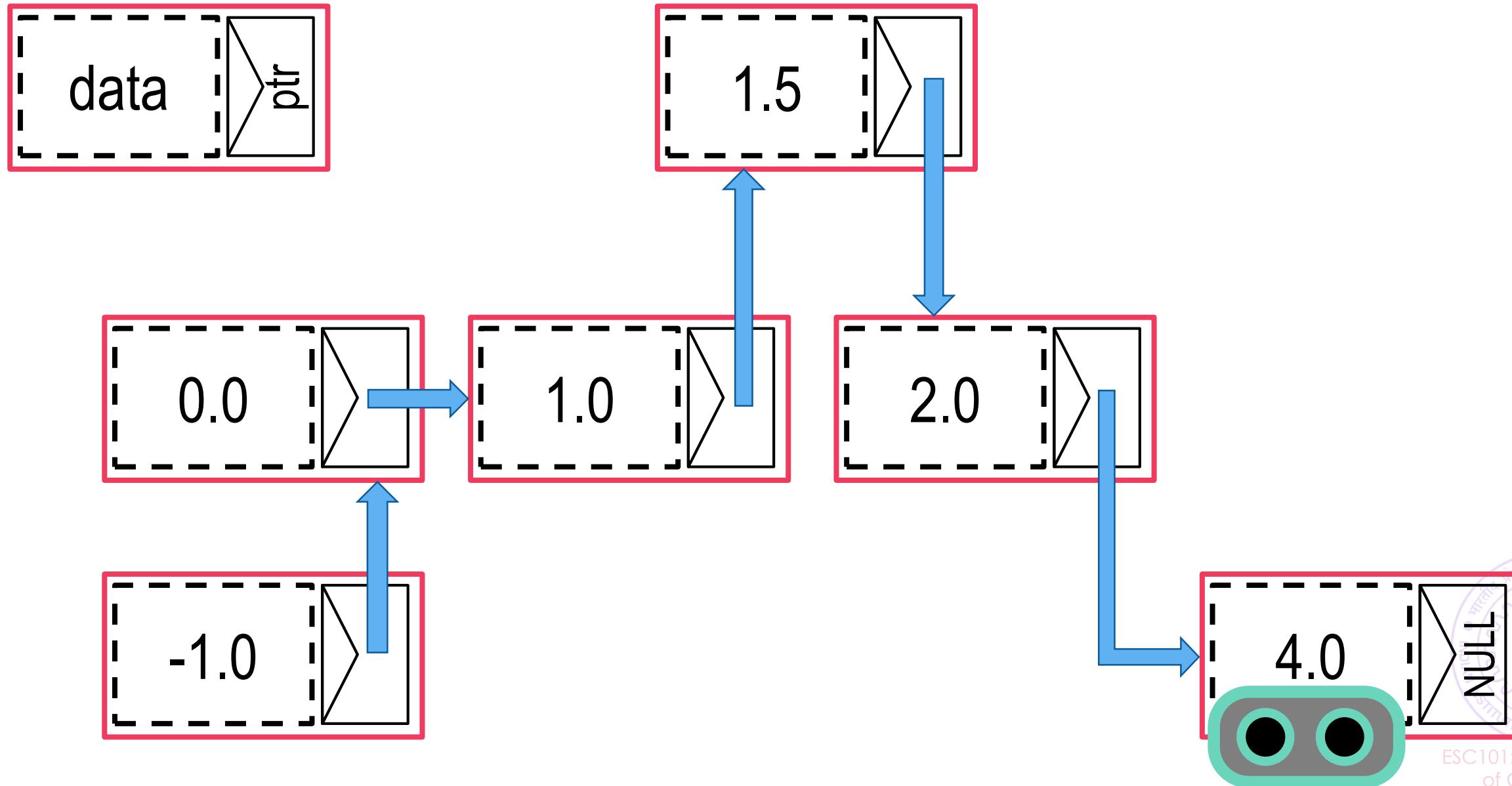
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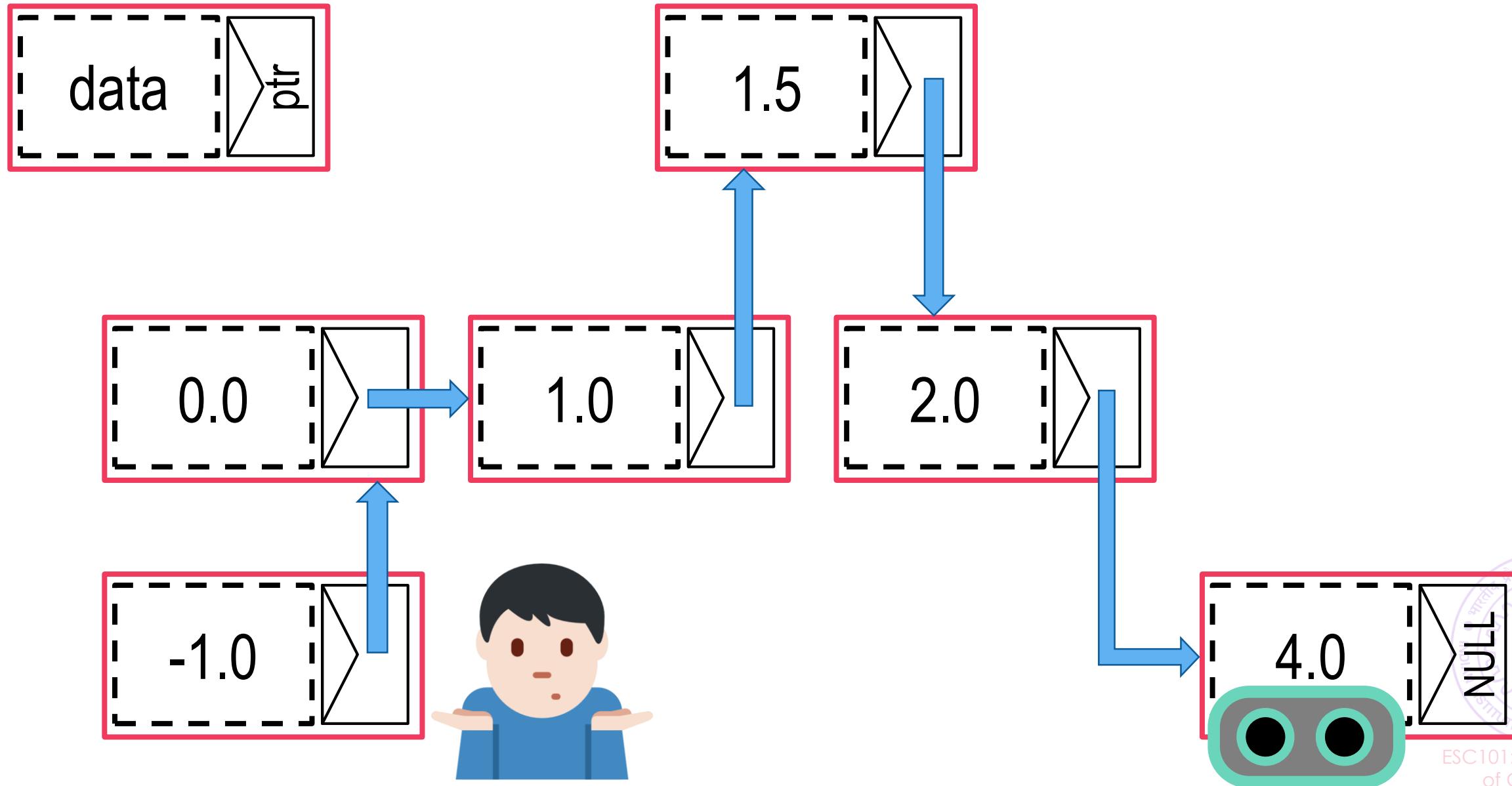
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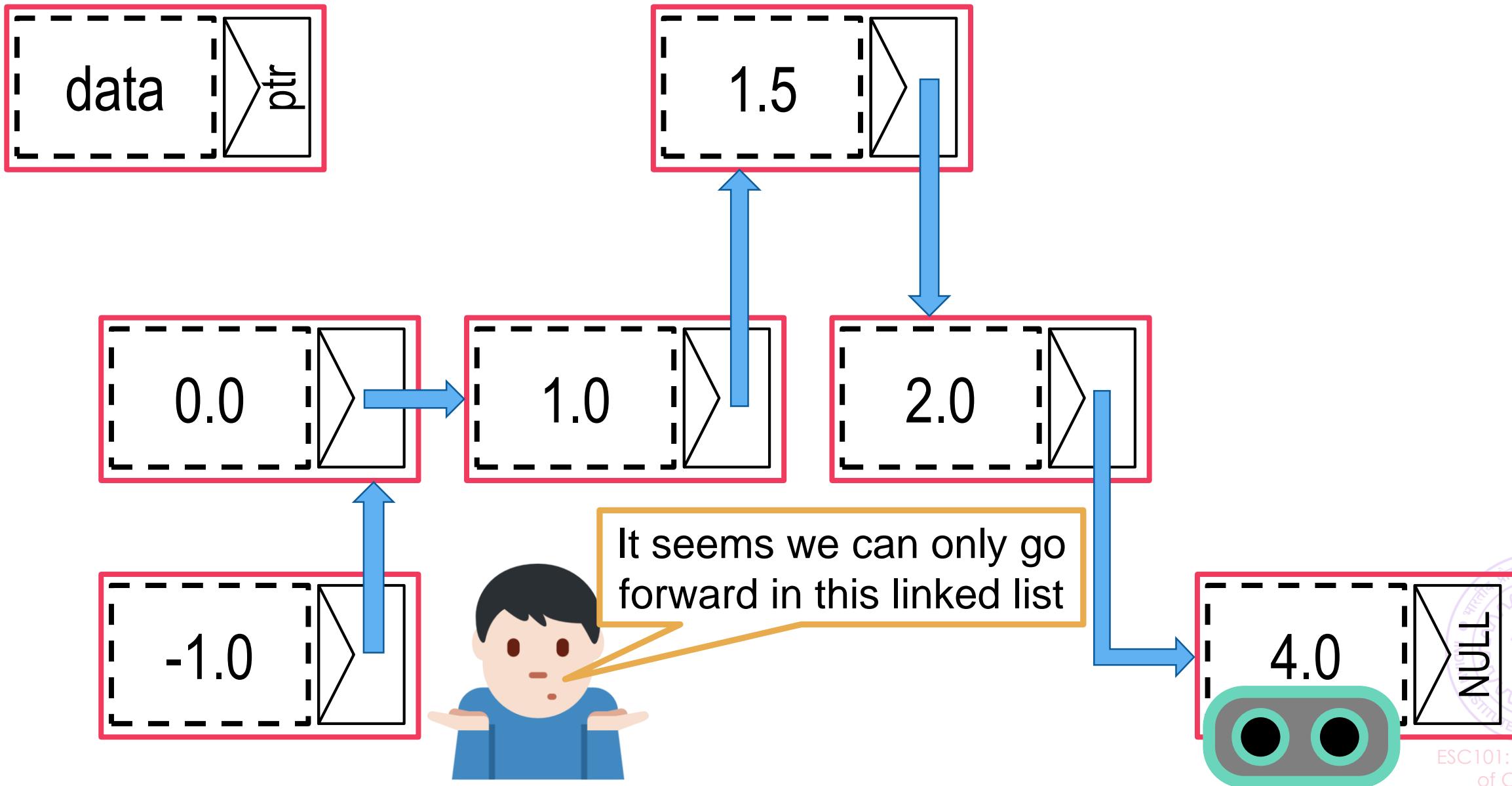
A Cartoon of Linked Lists



A Cartoon of Linked Lists



A Cartoon of Linked Lists

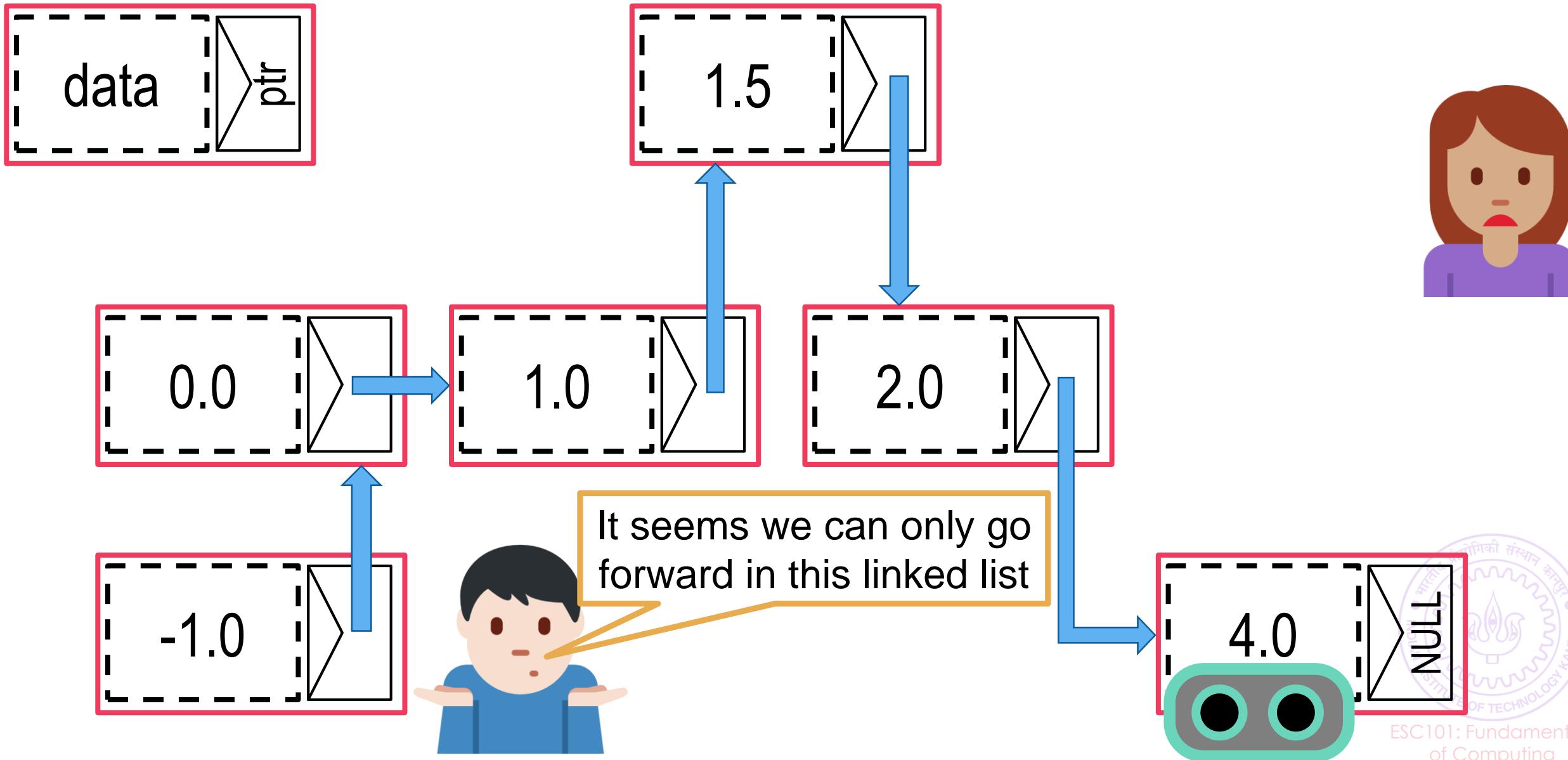


It seems we can only go forward in this linked list

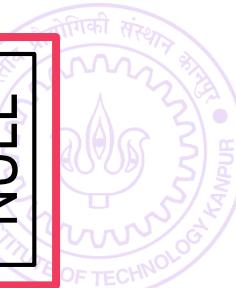
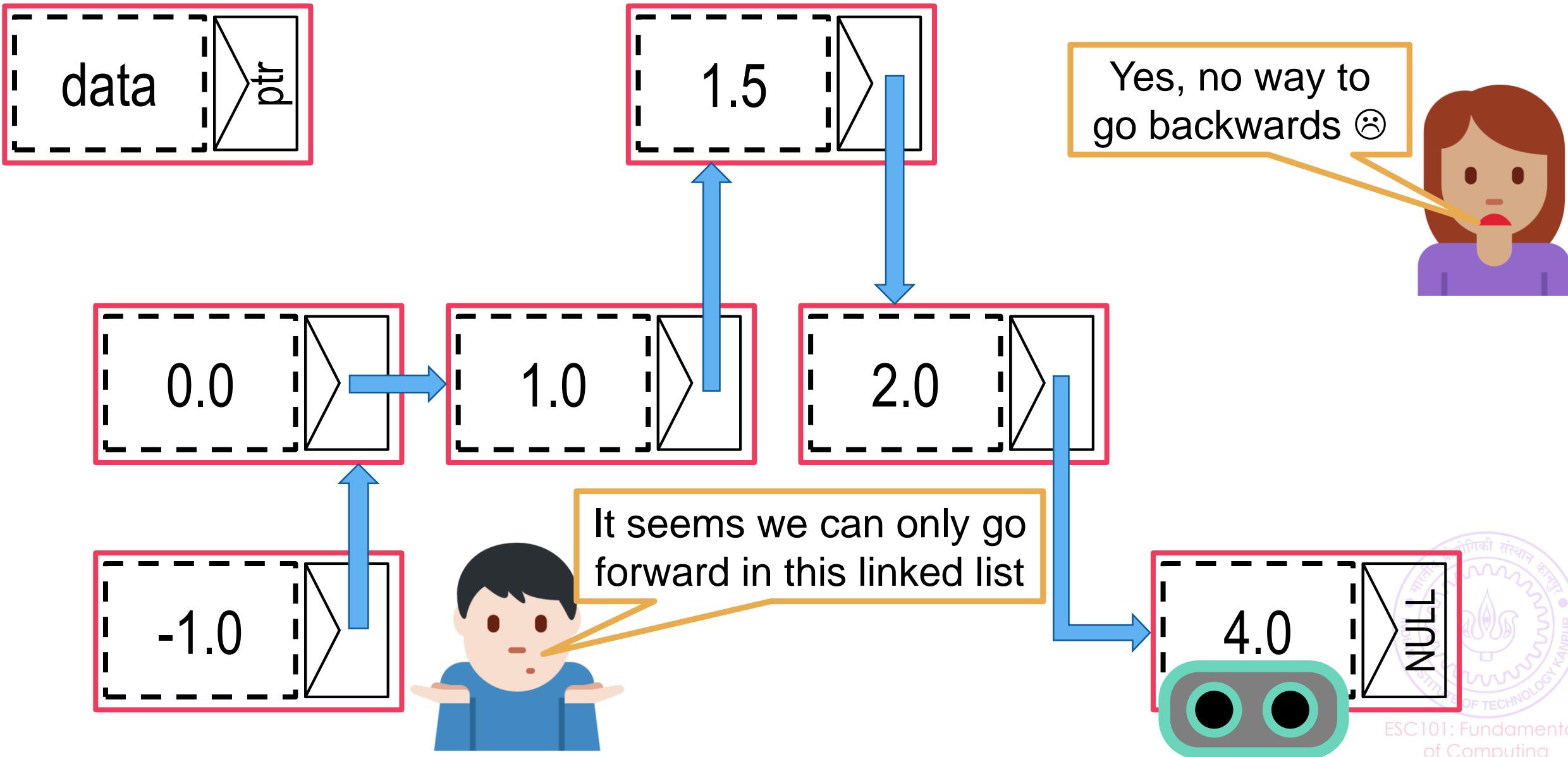


A Cartoon of Linked Lists

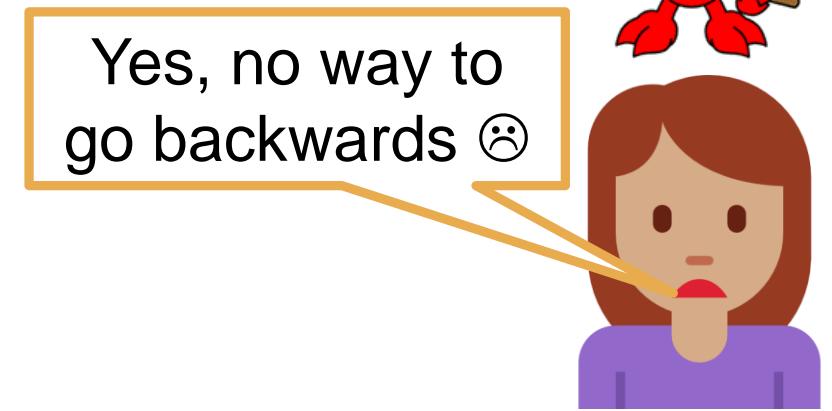
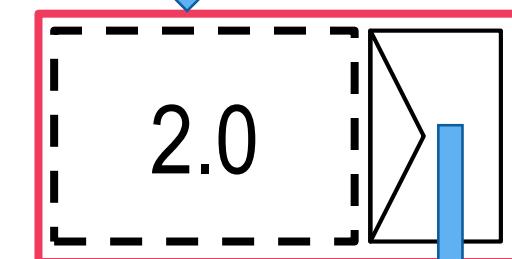
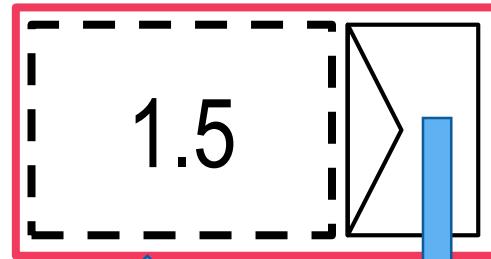
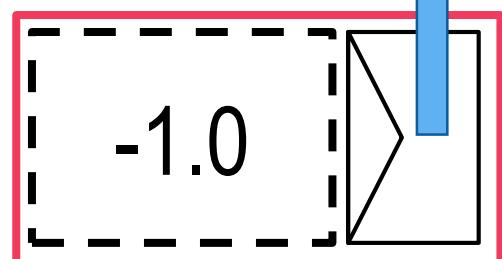
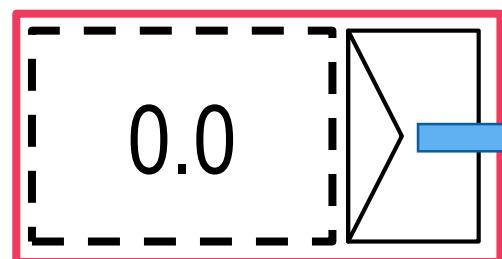
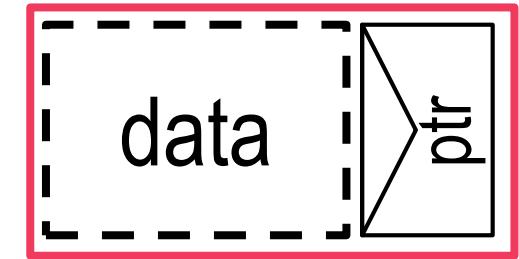
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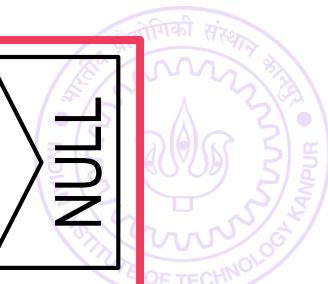
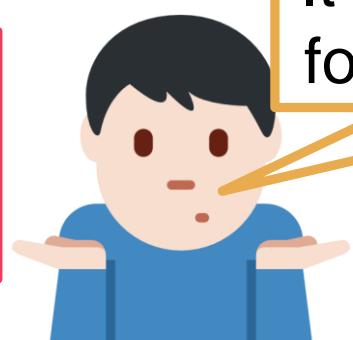
A Cartoon of Linked Lists



A Cartoon of Linked Lists



It seems we can only go forward in this linked list

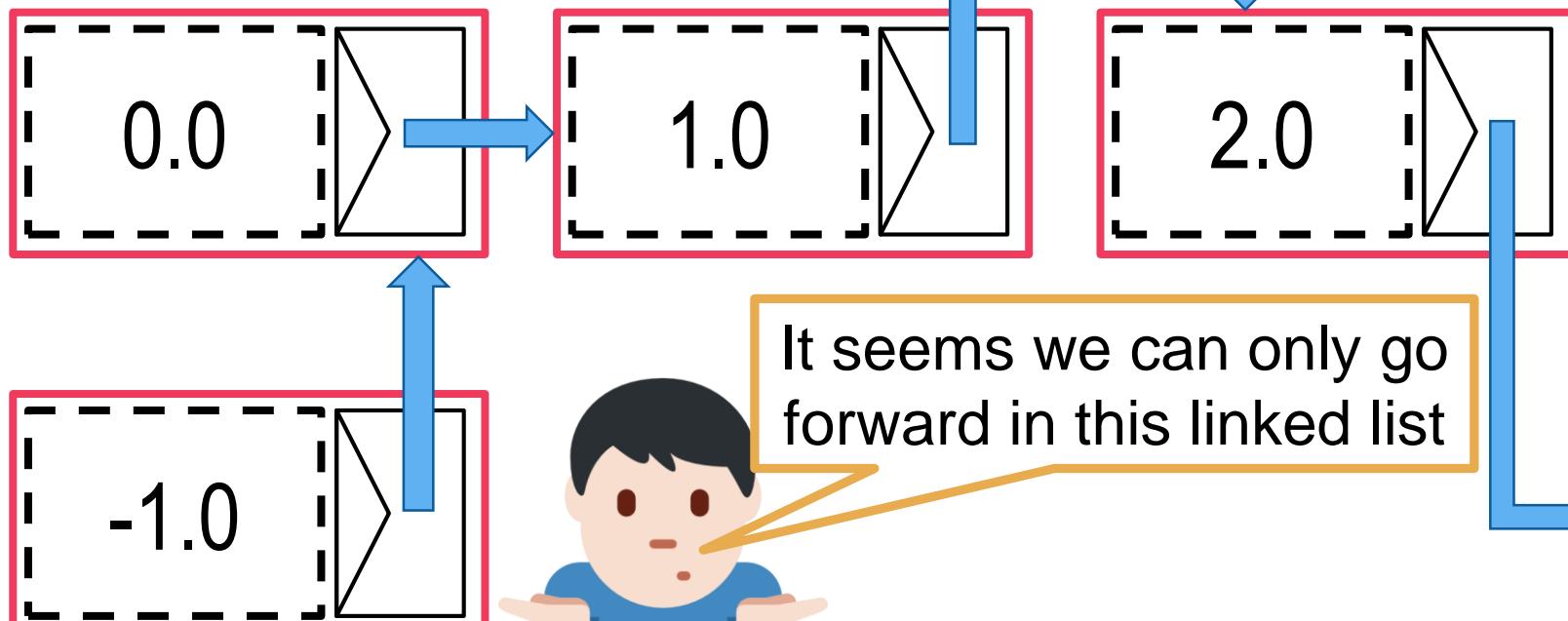


A Cartoon of Linked Lists

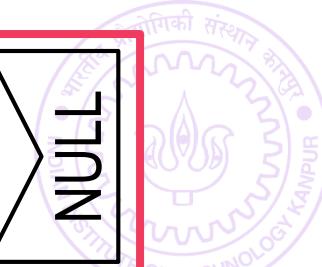
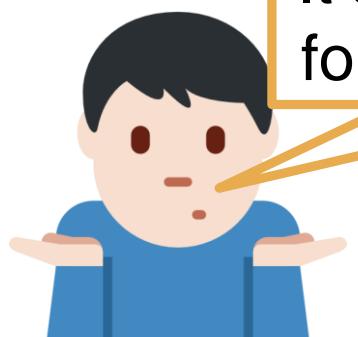
Fear not – a simple solution



Yes, no way to go backwards 😞



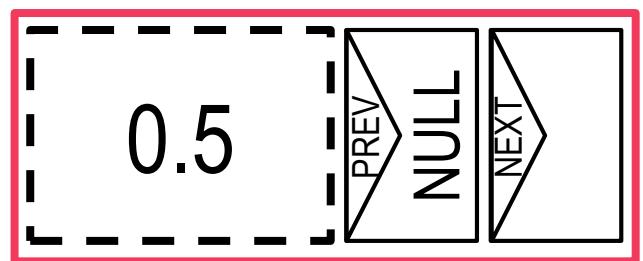
It seems we can only go forward in this linked list



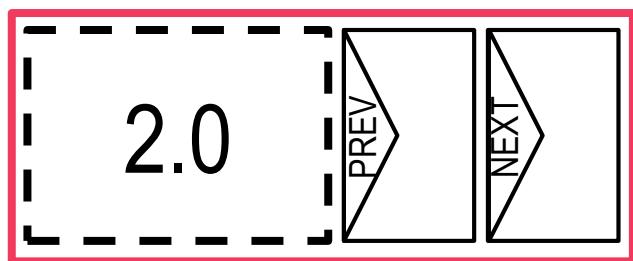
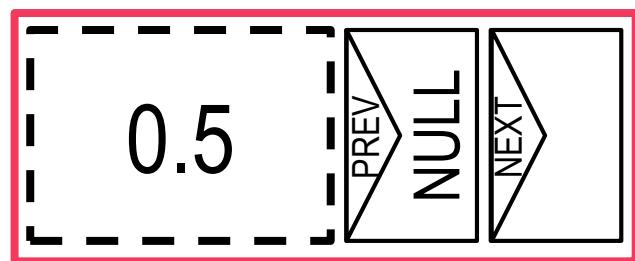
Doubly Linked Lists



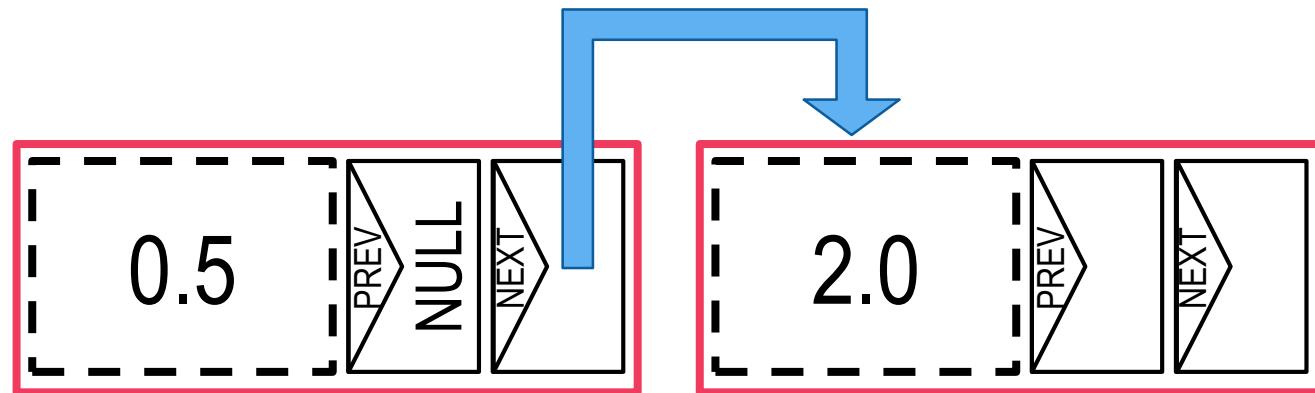
Doubly Linked Lists



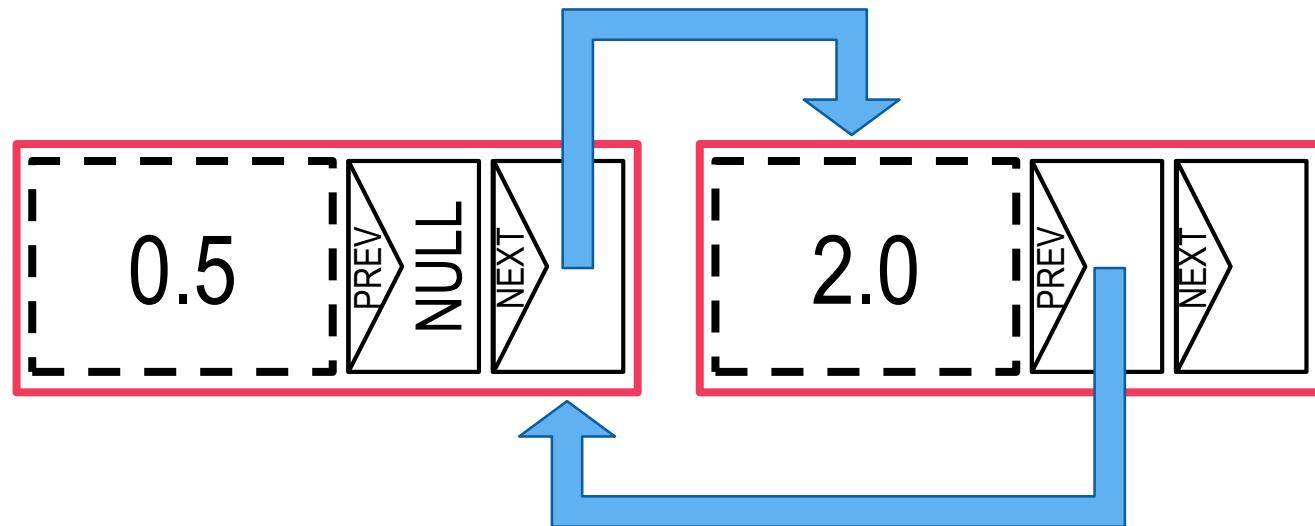
Doubly Linked Lists



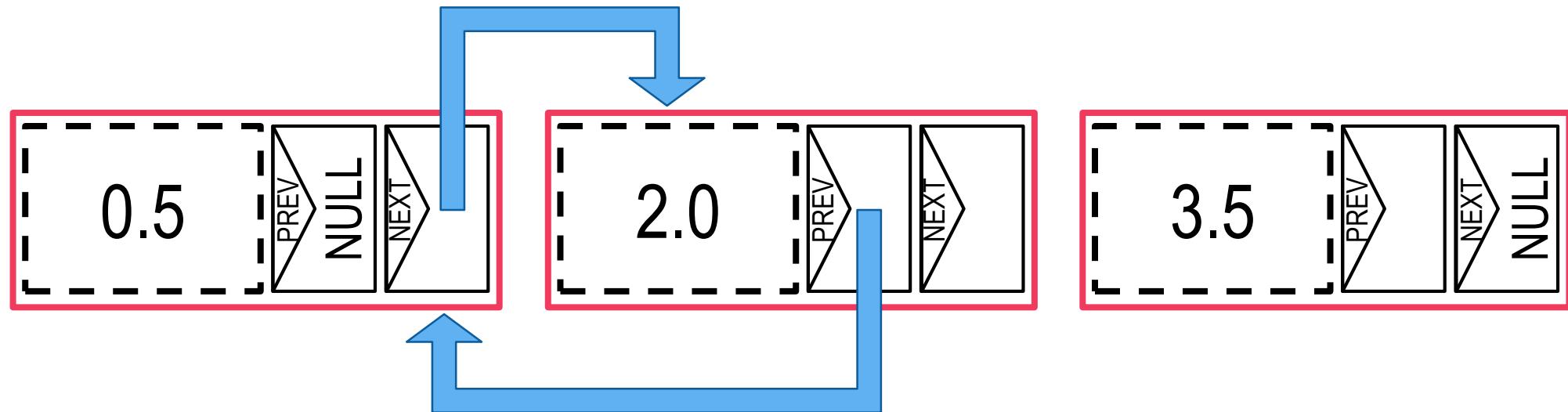
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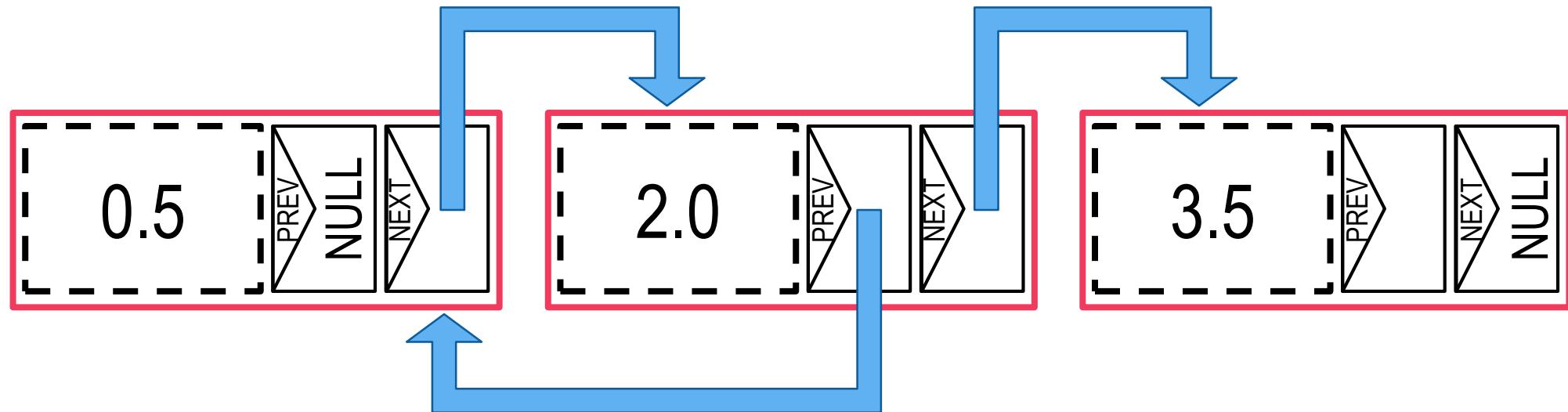
Doubly Linked Lists



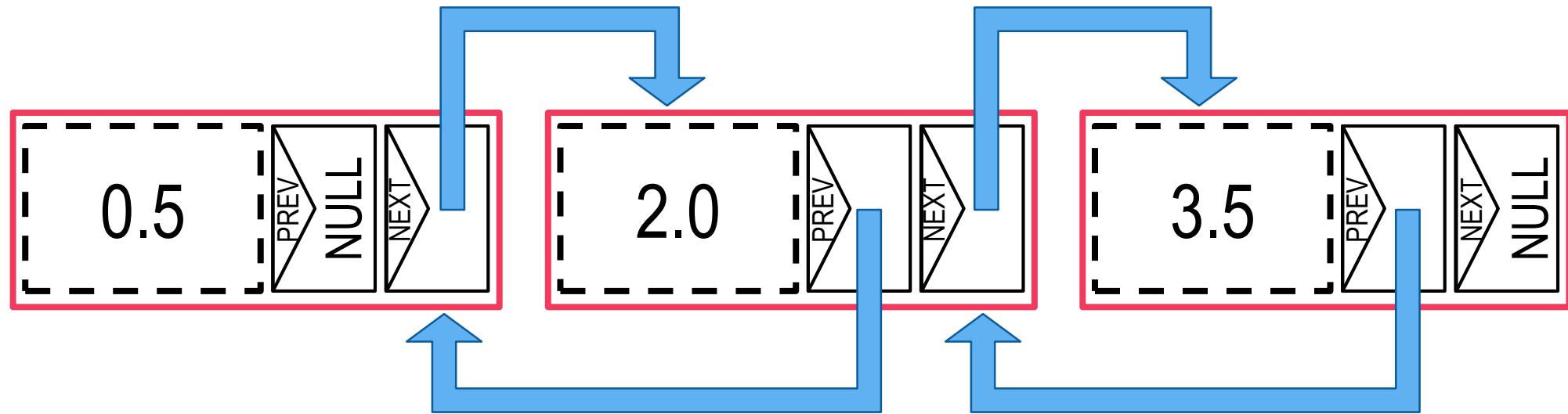
Doubly Linked Lists



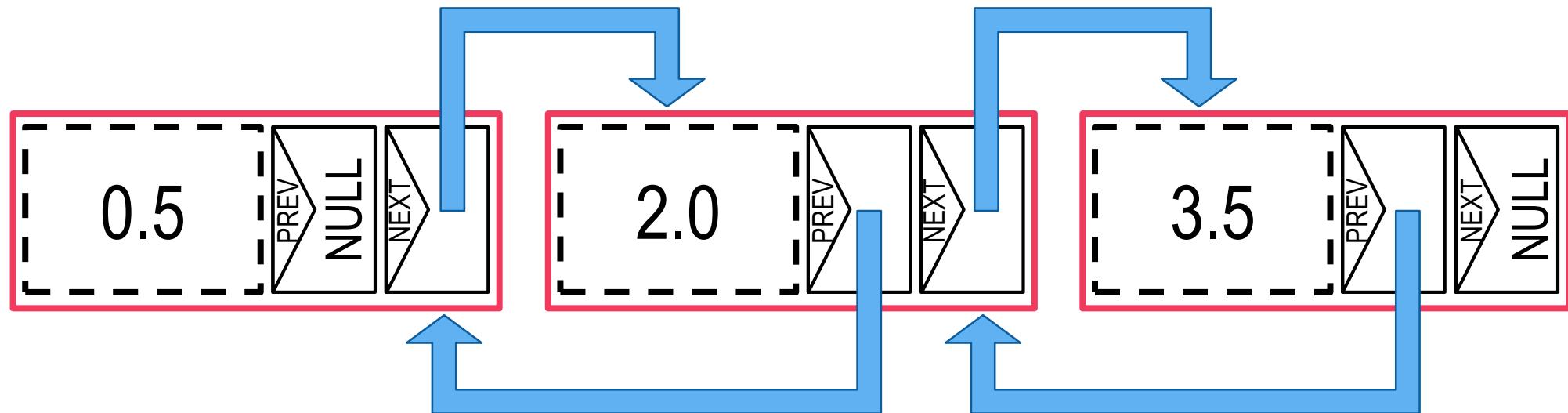
Doubly Linked Lists



Doubly Linked Lists



Doubly Linked Lists



Doubly Linked Lists

Allows traversal both ways.
However more code needed

