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**SINGAPORE**

CZ4031 - Database System Principles

Project 1 Report

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# Contents

<b>Contents</b>	<b>2</b>
<b>Introduction</b>	<b>3</b>
<b>Design of Storage Component</b>	<b>4</b>
<b>Linking Back to the Database storage (Mapping table)</b>	<b>5</b>
<b>Design of B+ Tree Component (Indexing)</b>	<b>6</b>
Insertion	7
Deletion	7
<b>Design of the B+ Tree in our problem</b>	<b>7</b>
BTree Methods	7
LeafNode Methods	8
InternalNode Methods	9
<b>Experimental Results</b>	<b>10</b>
<b>Contributions</b>	<b>29</b>

# Introduction

In this project, Java programming language is used to design and implement the storage and indexing components of a database management system.

The data contains the IMDb rating and votes information for movies, where:

- tconst (string) - alphanumeric unique identifier of the title
- averageRating – weighted average of all the individual user ratings
- numVotes - number of votes the title has received

Storage is implemented with the use of a text file and B+ tree is used for indexing. A B+ tree is an m-ary tree, whereby m is the maximum number of child pointers, with a variable but often large number of children per node. A B+ tree consists of a root, internal nodes and leaves.

The B+ Tree is an extension of the B Tree which allows efficient insertion, deletion and search operations.

In B Tree, keys and records both can be stored in the internal nodes as well as leaf nodes. On the other hand, in B+ tree, records (data) can only be stored on the leaf nodes while internal nodes can only store the key values.

The leaf nodes of a B+ tree are linked together in the form of singly linked lists using sibling pointers to make the search queries more efficient. Leaf nodes point to data in the database using data pointers.

# Design of Storage Component

The data that has been provided contains the IMDb rating and votes information for movies. It consists of three attributes (fields), namely 'tconst', 'averageRating' and 'numVotes':

1. 'tconst' is a unique ID. It is a string variable and is of fixed length
2. 'averageRating' is a rating given out of 10. It is a float variable and is of fixed length
3. 'numVotes' is the total number of votes given to each movie. It is a long variable and is of variable length

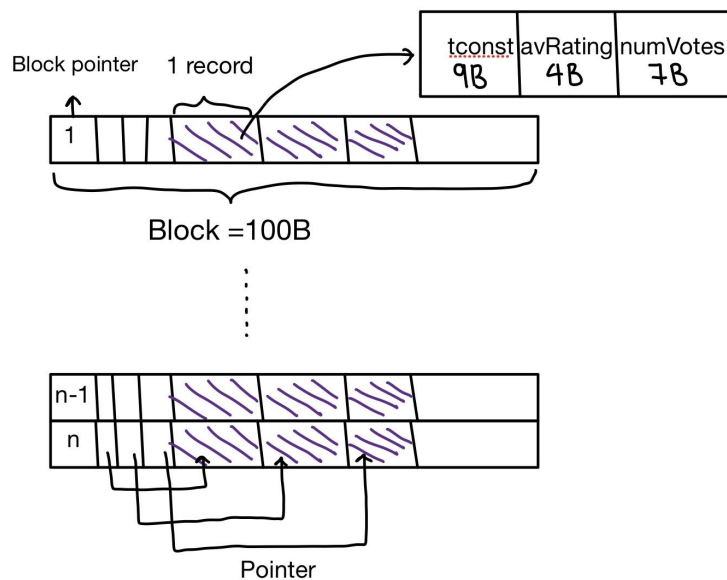


Fig 1. Implementation of the storage component with each block holding max 100B

Each record consists of data stored in these 3 fields.

Each data item in the relational database is represented using bytes. All data items are stored in the blocks as string variables and have a fixed length field. 'tconst' is an attribute that is stored using 9 bytes, 'averageRating' is stored using 4 bytes and 'numVotes' is stored using 7 bytes.

To pack the fields into the same tuple, each tuple is a row in the database containing the attributes 'tconst', 'averageRating', 'numVotes'. The format of the fields are fixed and each tuple has a fixed length of 20 bytes. Each record also has a pointer which points to the starting byte of each field, this pointer is represented by the integer value that denotes the starting bytes of the record.

Sample block: 30 48 65 tt0000001 5.6 1645 tt0000002 6.1 198 tt0000003 6.5 1342

As seen above, each line in the output file represents a block. Since all records have fixed lengths, unspanned mapping is used, there is no need to separate the records and the records

are moved to the subsequent block if it cannot be stored completely within the same block. The next record in the block is physically contiguous.

If the maximum block size is 100 bytes, then only 3 records are stored in each block as the number of bytes used to store records in each block is 80 bytes as 20 bytes are used as free space. When the maximum block size is increased to 500 bytes, the number of records that can be stored in the block is increased to 18 records, as 480 bytes of the block is used.

A unique index is made to point to each block and to keep track of the block that each record is in. The number of blocks used is proportional to the  $n^{\text{th}}$  index.

The pointer points to the subsequent record in the block to be accessed. Therefore, in order to refer to a particular record, this pointer can be used for faster navigation and search.

Once all the data has been divided into equal size records, the new data is written into a text file named 'output.txt'.

## Linking Back to the Database storage (Mapping table)



Output files - records\_100B and records\_500B act as the mapping tables between the B+ tree and the database.

The *id*, which is the last tuple inserted into each line in the database, is stored along with the *countBlocks*, which is the unique index of the block, in the records\_100B.txt and records\_500B.txt for easier reference.

Each pointer in the B+tree contains the unique movie id. This movie id is referenced against the mapping table to get the unique block index in which the tuple is stored.

## Design of B+ Tree Component (Indexing)

We initialize a B+ tree by setting  $m$ , the maximum number of pointers a node maintains to be 8, for a 100 bytes block and 32 for a 500 bytes block. Hence, the maximum number of keys the node maintains is 7 and 31 respectively.

Each leaf node contains a dictionary pair which consists of the key which is numVotes and a pointer which points to the location of the record in the block. The last pointer in the node points to the left sibling of the leaf node. Maintaining a linked list structure to connect all the leaf nodes together.

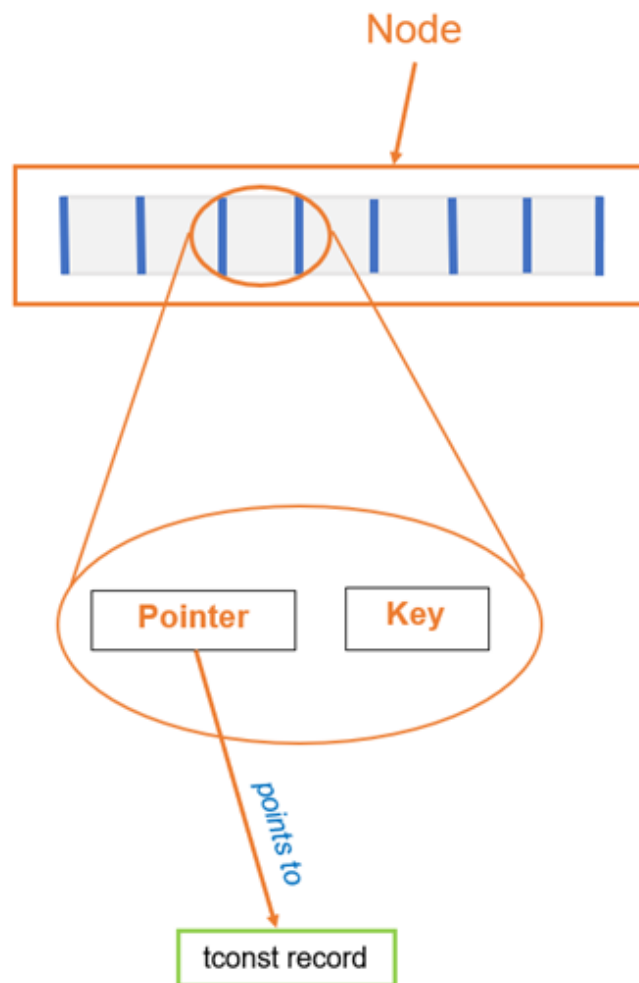


Fig 2. Illustration of a leaf node in B+ tree

The figure above depicts a leaf node in the B+ tree, and how the pointer, key and record interact with one another. There is one data pointer for every key, which points to the particular movieID in the database.

## Insertion

During insertion into the B+ tree, we first find the last leaf node containing the key that is less than the key to be inserted and insert the new key-value as a dictionary pair in the back of the leafnode.

An internal node is created when insertion into a particular leaf node is full (more than  $m-1$  keys) and the first key of the leaf node belonging to the split second half of the leaf node is added to the internal node, which is now the parent.

Height of the B+ tree increases when the nodes are full and do not have a parent, whereby a new parent will be created which increases the height of the tree.

## Deletion

During deletion from the B+ tree, we need to delete the key as well as the data from the leaves. To ensure that each node is not deficient (having keys less than  $\lceil m-1/2 \rceil$ ), the tree is balanced every time deletion is called on a particular key. If the node is deficient, then it will try to borrow from the left or right sibling of the same parent. In the code, the balancing tree is a recursive function that will be called on the parent of the node if the child nodes merge.

## Design of the B+ Tree in our problem

### BTree Methods

There are 3 fields (columns) in the dataset: tconst, averageRating and numVotes, as shown below:

tconst	averageRating	numVotes
tt0000001	5.6	1645
tt0000002	6.1	198
tt0000003	6.5	1342
tt0000004	6.2	120
tt0000005	6.2	2127
tt0000006	5.3	115
tt0000007	5.5	652
tt0000008	5.4	1807
tt0000009	5.9	154
tt0000010	6.9	6018

The B+ Tree has been built on the attribute "numVotes" by inserting the records sequentially.

File: BTree.java

Methods	Function
void getContentOfRootNodeAndFirstChild()	Traverse the tree and print the contents of the root node as well as the first child node that is referred by the first pointer of the root node.
void balanceTree(Node child)	Input: node that is deficient.  A recursive function that balances the tree by borrowing keys from siblings or merging to make up for the deficiency.
void insert(int key, double value)	Input: key → numVotes, value → pointer to block  Insert key-value pairs (dictionary pairs) in the B+tree
void traversal()	Print out all contents of all leaf nodes from left to right.
boolean delete(int key)	Input: key to be deleted  Finds leaf node containing key in B+tree and deletes the key. Calls balanceTree method if the leaf node is deficient.
ArrayList<Double> search(int lowerBound, int upperBound)	Input: lowerBound → lowest value in range, upperBound → highest value in range  Finds all leaf nodes containing keys and prints out their respective values.

## LeafNode Methods

File: LeafNode.java

The *LeafNode* class is a subclass which extends the functionality of the parent class *Node*. The leaf nodes form the first level of the index. Each node can contain a maximum of  $m-1$  keys and a minimum of  $\lceil m/2 \rceil - 1$  keys. Some of the methods in this class include:

Methods	Function
int linearSearch(int key)	Input: key → numVotes  Performs a linear search through all the keys



	in the node and returns the corresponding index of the key-value pair in the leaf node.
void printAllDictionaryPairs()	Prints contents of the dictionary pairs, i.e. all the key-value information.
int getNoofIndexblocksaccessed(int key1, int key2)	Input: key1, key2  Increases the count by 1 each time an index block is accessed.
void delete(int index)	Input: index position of key in leaf node  Deletes the key in the leaf node and decrements the numPairs by 1.
boolean insert(DictionaryPair dp)	Input: DictionaryPair containing key-value  Inserts the dictionary pair into the tree and increments the total number of keys in the node by 1 if the node is not full.

## InternalNode Methods

File: InternalNode.java

The internal nodes refer to all the non-leaf nodes, forming the other levels of a multilevel index. Each of these nodes can contain a maximum of  $m$  children (represented as *degree*) and a minimum of  $m/2$  children. Some of the methods in this class include:

Methods	Function
void appendChildPointer(Node pointer)	Input: child pointer  This method appends the child pointer of its sibling to its list of child pointers.
int findIndexOfPointer(Node pointer)	Input: child pointer  Get index of child pointer in parent node.
void insertChildPointer(Node pointer, int index)	Input: pointer, index of child pointer in internal node  Inserts the child pointer at the given index and increments the degree of the B+ tree.
void removeKey(int index)	Input: index to be removed



3		tt0149695, tt0163456, tt0184456, tt0214362, tt0218000, tt0289115, tt0303487, tt0314564, tt0327085, tt0327546, tt0398451, tt0424365, tt0450955, tt0514442, tt0517623, tt0558715, tt0582480, tt0588114, tt0588139, tt0588187, tt0588214, tt0629708, tt0640298, tt0640308, tt0647512, tt0716912, tt0720140, tt0807689, tt1169169, tt1261908, tt1340802, tt1365490, tt1371697, tt1376451, tt1421383, tt1515736, tt1535989, tt1571100, tt1592534, tt1632756, tt1640740, tt1648683, tt1684558, tt1711021, tt1727519, tt1857596, tt2040651, tt2236257, tt2247719, tt2365211, tt2662228, tt2764038, tt2813064, tt3127434, tt3203366, tt3231390, tt3263598, tt3276280, tt3398808, tt3440780, tt3592904, tt3683072, tt3916858, tt4038966, tt4247300, tt4392820, tt4493298, tt4627488, tt4680568, tt4713652, tt4897608, tt6038946, tt6054370, tt6222376, tt6232560, tt6318954, tt6985094, tt7008310, tt7431738, tt7457714, tt7517336, tt7689514, tt7860116, tt8044824, tt8960572, tt9454484, tt9614612, tt9680914, tt9895050,	tt0149695, tt0163456, tt0184456, tt0214362, tt0218000, tt0289115, tt0303487, tt0314564, tt0327085, tt0327546, tt0398451, tt0424365, tt0450955, tt0514442, tt0517623, tt0558715, tt0582480, tt0588114, tt0588139, tt0588187, tt0588214, tt0629708, tt0640298, tt0640308, tt0647512, tt0716912, tt0720140, tt0807689, tt1169169, tt1261908, tt1340802, tt1365490, tt1371697, tt1376451, tt1421383, tt1515736, tt1535989, tt1571100, tt1592534, tt1632756, tt1640740, tt1648683, tt1684558, tt1711021, tt1727519, tt1857596, tt2040651, tt2236257, tt2247719, tt2365211, tt2662228, tt2764038, tt2813064, tt3127434, tt3203366, tt3231390, tt3263598, tt3276280, tt3398808, tt3440780, tt3592904, tt3683072, tt3916858, tt4038966, tt4247300, tt4392820, tt4493298, tt4627488, tt4680568, tt4713652, tt4897608, tt6038946, tt6054370, tt6222376, tt6232560, tt6318954, tt6985094, tt7008310, tt7431738, tt7457714, tt7517336, tt7689514, tt7860116, tt8044824, tt8960572, tt9454484, tt9614612, tt9680914, tt9895050,
	The number and the content of index nodes the process accesses	The total number of index nodes accessed is: 28  The contents of the first 5 index nodes are: key is: 499 value is: 7410352.0 key is: 499 value is: 7657428.0 key is: 499 value is: 8160064.0 key is: 500 value is: 13674.0  key is: 500 value is: 24561.0 key is: 500 value is: 28277.0 key is: 500 value is: 41956.0 key is: 500 value is: 47361.0  key is: 500 value is: 47434.0	The total number of index nodes accessed is: 8  The contents of the first 5 index nodes are: are: key is: 499 value is: 2927080.0 key is: 499 value is: 3054776.0 key is: 499 value is: 3264494.0 key is: 499 value is: 3344392.0 key is: 499 value is: 3471822.0 key is: 499 value is: 3602560.0 key is: 499 value is: 3773240.0 key is: 499 value is: 4012552.0 key is: 499 value is: 4160706.0 key is: 499 value is: 4502154.0

		<p>key is: 500 value is: 51500.0 key is: 500 value is: 52815.0 key is: 500 value is: 54298.0</p> <hr/> <p>key is: 500 value is: 62345.0 key is: 500 value is: 69064.0 key is: 500 value is: 70783.0 key is: 500 value is: 82275.0</p> <hr/>	<p>key is: 499 value is: 5179380.0 key is: 499 value is: 5304186.0 key is: 499 value is: 5685400.0 key is: 499 value is: 5706306.0 key is: 499 value is: 6002432.0 key is: 500 value is: 13674.0 key is: 499 value is: 6199772.0 key is: 499 value is: 6388074.0 key is: 499 value is: 6597246.0 key is: 499 value is: 6793888.0 key is: 499 value is: 6975598.0 key is: 499 value is: 7014318.0 key is: 499 value is: 7117812.0 key is: 499 value is: 7292950.0 key is: 499 value is: 7373264.0 key is: 499 value is: 7410352.0 key is: 499 value is: 7657428.0 key is: 499 value is: 8160064.0</p> <hr/> <p>key is: 500 value is: 24561.0 key is: 500 value is: 28277.0 key is: 500 value is: 41956.0 key is: 500 value is: 47361.0 key is: 500 value is: 47434.0 key is: 500 value is: 51500.0 key is: 500 value is: 52815.0 key is: 500 value is: 54298.0 key is: 500 value is: 62345.0 key is: 500</p>
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			<p>value is: 69064.0 key is: 500 value is: 70783.0 key is: 500 value is: 82275.0 key is: 500 value is: 82841.0 key is: 500 value is: 85198.0 key is: 500 value is: 90356.0 key is: 500 value is: 99259.0</p> <hr/> <p>key is: 500 value is: 100811.0 key is: 500 value is: 106600.0 key is: 500 value is: 119415.0 key is: 500 value is: 120462.0 key is: 500 value is: 149695.0 key is: 500 value is: 163456.0 key is: 500 value is: 184456.0 key is: 500 value is: 214362.0 key is: 500 value is: 218000.0 key is: 500 value is: 289115.0 key is: 500 value is: 303487.0 key is: 500 value is: 314564.0 key is: 500 value is: 327085.0 key is: 500 value is: 327546.0 key is: 500 value is: 398451.0 key is: 500 value is: 424365.0</p> <hr/> <p>key is: 500 value is: 450955.0 key is: 500 value is: 514442.0 key is: 500 value is: 517623.0 key is: 500 value is: 558715.0 key is: 500</p>
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			value is: 582480.0 key is: 500 value is: 588114.0 key is: 500 value is: 588139.0 key is: 500 value is: 588187.0 key is: 500 value is: 588214.0 key is: 500 value is: 629708.0 key is: 500 value is: 640298.0 key is: 500 value is: 640308.0 key is: 500 value is: 647512.0 key is: 500 value is: 716912.0 key is: 500 value is: 720140.0 key is: 500 value is: 807689.0
	The number and the content of data blocks the process accesses	<p>The content of the top 5 data blocks are:</p> <hr/> This is the data block number: 1198 30 46 63 tt0013672 6.7 25 <b>tt0013674 7.0 500</b> tt0013679 6.9 7	*Movie Id 13674.0 with numvotes = 500 is in data block number 138 100 116 132 148 164 181 197 213 230 245 261 277 292 309 325 342 359 375 391 407 422 438 454 470 486 501 tt0013627 5.2 10 tt0013629 6.7 25 tt0013631 6.6 12 tt0013658 6.9 31 tt0013662 6.9 418 tt0013668 6.7 22 tt0013672 6.7 25 <b>tt0013674 7.0 500</b> tt0013679 6.9 7 tt0013681 5.6 14 tt0013682 7.5 64 tt0013687 7.1 7 tt0013688 6.6 642 tt0013690 5.3 97 tt0013704 6.0 118 tt0013705 5.8 136 tt0013710 7.0 12 tt0013716 6.2 12 tt0013719 6.5 22 tt0013724 6.0 8 tt0013727 6.9 10 tt0013728 5.9 49 tt0013730 6.8 83 tt0013735 5.1 73 tt0013736 6.8 8 tt0013739 6.2 6
		<hr/> This is the data block number: 3006 30 47 63 <b>tt0024561 6.8 500</b> tt0024562 5.4 10 tt0024563 6.0 93	
		<hr/> This is the data block number: 3942 30 47 62 <b>tt0028277 7.7 500</b> tt0028278 7.6 5 tt0028279 6.5 131	
		<hr/> This is the data block number: 7593 30 47 63 <b>tt0041956 6.5 500</b> tt0041957 7.7 10 tt0041958 7.6 5154	
		<hr/> This is the data block number: 9062 30 47 62 <b>tt0047361 7.3 500</b> tt0047362 5.8 5 tt0047363 6.7 30 Number of Data Blocks accessed is 110	<hr/> Movie Id 24561.0 with numvotes = 500 is in data block number 346 100 116 132 149 164 180 197 214 231 247 263 279 296 314 331 347 362 379 396 413 429 446 463 480 496 512 tt0024531 6.9 11 tt0024532 5.1 45 tt0024534 7.2 213 tt0024535 7.2 5 tt0024536 4.8 13 tt0024537 6.4 303 tt0024538 6.4 645 tt0024539 6.5 578 tt0024542 1.6 10 tt0024545 4.2 57 tt0024546 6.8 25 tt0024547 5.2 300 tt0024548 6.3 5257 tt0024549 6.0 361 tt0024550 6.4 24 tt0024551 2.9 9 tt0024553 5.9 137

		<p>tt0024554 5.3 822 tt0024555 5.5 195  tt0024558 6.4 11 tt0024559 6.1 140  tt0024560 6.9 397 <b>tt0024561 6.8 500</b>  tt0024562 5.4 10 tt0024563 6.0 93  tt0024564 6.0 55</p> <hr/> <p>Movie Id 28277.0 with numvotes = 500 is in  data block number 454  100 118 134 150 166 182 198 214 231 247  263 280 295 312 328 345 362 377 394 410  426 444 460 477 492 509 tt0028249 7.4  2845 tt0028250 6.1 76 tt0028251 6.9 17  tt0028252 6.7 19 tt0028254 6.2 58  tt0028255 6.5 99 tt0028256 6.0 86  tt0028257 6.3 124 tt0028258 6.3 54  tt0028259 6.4 25 tt0028260 6.2 138  tt0028264 7.0 7 tt0028267 7.8 444  tt0028268 4.8 29 tt0028269 6.7 765  tt0028270 6.4 247 tt0028271 6.0 6  tt0028272 6.1 282 tt0028273 6.2 28  tt0028274 6.6 71 tt0028275 6.5 1246  tt0028276 5.9 30 <b>tt0028277 7.7 500</b>  tt0028278 7.6 5 tt0028279 6.5 131  tt0028280 5.7 35</p> <hr/> <p>Movie Id 41956.0 with numvotes = 500 is in  data block number 876  100 117 135 153 170 186 204 224 241 257  274 291 309 327 344 361 378 395 411 427  445 461 477 493 510 527 tt0041953 6.9  469 tt0041954 7.3 2435 tt0041955 6.7  1119 <b>tt0041956 6.5 500</b> tt0041957 7.7 10  tt0041958 7.6 5154 tt0041959 8.1 155251  tt0041961 6.0 308 tt0041962 6.4 25  tt0041963 6.7 914 tt0041966 6.4 248  tt0041967 6.4 1793 tt0041968 7.3 3571  tt0041969 6.1 216 tt0041971 5.6 143  tt0041974 6.5 396 tt0041975 6.8 395  tt0041976 5.5 76 tt0041977 6.6 19  tt0041978 7.6 1106 tt0041979 6.5 55  tt0041980 5.9 11 tt0041981 5.5 27  tt0041982 6.6 307 tt0041983 6.3 979  tt0041984 7.2 6</p> <hr/> <p>Movie Id 47361.0 with numvotes = 500 is in  data block number 1045  100 116 132 147 163 180 196 213 231 247  264 280 296 312 329 345 361 378 393 409  425 443 460 476 492 509 tt0047339 5.4 11  tt0047340 5.4 29 tt0047341 4.4 5  tt0047342 4.4 26 tt0047343 7.8 618  tt0047345 5.9 19 tt0047348 5.9 750  tt0047349 6.6 1352 tt0047351 6.5 79  tt0047353 7.1 335 tt0047355 5.9 99  tt0047356 7.0 10 tt0047357 6.4 27  tt0047358 5.9 224 tt0047359 6.7 20</p>
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			tt0047360 4.6 12 <b>tt0047361 7.3 500</b> tt0047362 5.8 5 tt0047363 6.7 30 tt0047364 4.3 11 tt0047365 6.2 2363 tt0047366 6.4 317 tt0047367 5.5 40 tt0047368 5.3 42 tt0047369 4.8 232 tt0047370 6.7 1234 <hr/> Number of Data Blocks accessed is 110
	The average of "averageRating"s of the records that are returned	Average of averageRating is: 6.735135135135137	Average of averageRating is: 6.735135135135137
4	Movies with the attribute "numVotes" from 30,000 to 40,000	Movie Ids with numvotes = 30,000 and numvotes = 40,000: tt0054167, tt0026778, tt0091828, tt1456941, tt0110443, tt3361792, tt0105629, tt0257516, tt0489664, tt2027128, tt2303687, tt0078718, tt0857265, tt1435513, tt2712740, tt0108211, tt0268397, tt9053874, tt8758202, tt0082533, tt1741256, tt3139086, tt0082089, tt0113253, tt0056111, tt4396630, tt7668518, tt0037382, tt0204993, tt0377091, tt0417001, tt0880502, tt1174730, tt3385524, tt0105643, tt0439662, tt0482088, tt0408777, tt1094249, tt1629757, tt1672723, tt0059026, tt4283054, tt0485601, tt3544082, tt0108308, tt1500491, tt0090887, tt0092593, tt8201170, tt0100994, tt0088526, tt0105121, tt0060665, tt0899106, tt0845046, tt0098749, tt0479968, tt1668191, tt2294677, tt0043338, tt0083946, tt0096694, tt0088814, tt1641384, tt5691670, tt0116654, tt1588398, tt0458413, tt3398268, tt4131606, tt0192614, tt3247714, tt0380599, tt1615918, tt0053488, tt0093148, tt0110527, tt0378947, tt0802999, tt1372686, tt2088003, tt0086687, tt1971352, tt2213054, tt0090390, tt3735246, tt1567448, tt0419843, tt6769208, tt3986820, tt2555736, tt4535650, tt0379865, tt4669986, tt0045810, tt0104361, tt3698408, tt1411704, tt6317068, tt0102526, tt1127715, tt0092494, tt1462900, tt7826376, tt0346631, tt0814335, tt0078723, tt4126476, tt5116302, tt0073582,	Movie Ids with numvotes = 30,000 and numvotes = 40,000: tt0054167, tt0026778, tt0091828, tt1456941, tt0110443, tt3361792, tt0105629, tt0257516, tt0489664, tt2027128, tt2303687, tt0078718, tt0857265, tt1435513, tt2712740, tt0108211, tt0268397, tt9053874, tt8758202, tt0082533, tt1741256, tt3139086, tt0082089, tt0113253, tt0056111, tt4396630, tt7668518, tt0037382, tt0204993, tt0377091, tt0417001, tt0880502, tt1174730, tt3385524, tt0105643, tt0439662, tt0482088, tt0408777, tt1094249, tt1629757, tt1672723, tt0059026, tt4283054, tt0485601, tt3544082, tt0108308, tt1500491, tt0090887, tt0092593, tt8201170, tt0100994, tt0088526, tt0105121, tt0060665, tt0899106, tt0845046, tt0098749, tt0479968, tt1668191, tt2294677, tt0043338, tt0083946, tt0096694, tt0088814, tt1641384, tt5691670, tt0116654, tt1588398, tt0458413, tt3398268, tt4131606, tt0192614, tt3247714, tt0380599, tt1615918, tt0053488, tt0093148, tt0110527, tt0378947, tt0802999, tt1372686, tt2088003, tt0086687, tt1971352, tt2213054, tt0090390, tt3735246, tt1567448, tt0419843, tt6769208, tt3986820, tt2555736, tt4535650, tt0379865, tt4669986, tt0045810, tt0104361, tt3698408, tt1411704, tt6317068, tt0102526, tt1127715, tt0092494, tt1462900, tt7826376, tt0346631, tt0814335, tt0078723,



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		tt1423995, tt6742252,	tt1698641, tt0114287, tt0421729, tt1423995, tt6742252,
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	<p>The number and the content of index nodes the process accesses</p>	<p>The total number of index nodes accessed is: 186</p> <p>The contents of the first 5 index nodes are:</p> <p>key is: 29975 value is: 1668746.0 key is: 29978 value is: 285462.0 key is: 29996 value is: 2326554.0 key is: 29975 value is: 3666024.0 key is: 29988 value is: 3922798.0 key is: 29982 value is: 4934950.0 key is: 30022 value is: 54167.0</p> <hr/> <p>key is: 30034 value is: 26778.0 key is: 30037 value is: 91828.0 key is: 30049 value is: 1456941.0 key is: 30053 value is: 110443.0 key is: 30041 value is: 3361792.0</p> <hr/> <p>key is: 30056 value is: 105629.0 key is: 30078 value is: 257516.0 key is: 30078 value is: 489664.0 key is: 30085 value is: 2027128.0 key is: 30081 value is: 2303687.0</p> <hr/> <p>key is: 30090 value is: 78718.0 key is: 30136 value is: 857265.0 key is: 30144 value is: 1435513.0 key is: 30149 value is: 2712740.0</p> <hr/>	<p>The total number of index nodes accessed is: 46</p> <p>The contents of the first 5 index nodes are:</p> <p>key is: 29910 value is: 40725.0 key is: 29919 value is: 115200.0 key is: 29954 value is: 2326612.0 key is: 29956 value is: 3179568.0 key is: 29959 value is: 2398231.0 key is: 29962 value is: 441796.0 key is: 29974 value is: 131613.0 key is: 29975 value is: 1668746.0 key is: 29978 value is: 285462.0 key is: 29996 value is: 2326554.0 key is: 30022 value is: 54167.0 key is: 30034 value is: 26778.0 key is: 30037 value is: 91828.0 key is: 30049 value is: 1456941.0 key is: 30053 value is: 110443.0 key is: 30056 value is: 105629.0 key is: 30041 value is: 3361792.0 key is: 29975 value is: 3666024.0 key is: 29988 value is: 3922798.0 key is: 29949 value is: 4181172.0 key is: 29982 value is: 4934950.0 key is: 29956 value is: 7908628.0</p> <hr/> <p>key is: 30078 value is: 257516.0 key is: 30078 value is: 489664.0 key is: 30081 value is: 2303687.0 key is: 30085</p>
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			value is: 2027128.0 key is: 30090 value is: 78718.0 key is: 30136 value is: 857265.0 key is: 30144 value is: 1435513.0 key is: 30149 value is: 2712740.0 key is: 30158 value is: 108211.0 key is: 30158 value is: 268397.0 key is: 30177 value is: 82533.0 key is: 30195 value is: 1741256.0 key is: 30206 value is: 3139086.0 key is: 30221 value is: 82089.0 key is: 30240 value is: 113253.0 key is: 30246 value is: 56111.0 key is: 30247 value is: 4396630.0 key is: 30248 value is: 7668518.0 key is: 30175 value is: 8758202.0 key is: 30168 value is: 9053874.0 <hr/> key is: 30254 value is: 37382.0 key is: 30259 value is: 204993.0 key is: 30262 value is: 377091.0 key is: 30275 value is: 417001.0 key is: 30319 value is: 1174730.0 key is: 30333 value is: 880502.0 key is: 30341 value is: 105643.0 key is: 30354 value is: 439662.0 key is: 30361 value is: 1629757.0 key is: 30370 value is: 1094249.0 key is: 30376 value is: 482088.0
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			<p> key is: 30391  value is: 408777.0  key is: 30395  value is: 1672723.0  key is: 30402  value is: 59026.0  key is: 30423  value is: 485601.0  key is: 30446  value is: 108308.0  key is: 30326  value is: 3385524.0  key is: 30431  value is: 3544082.0  key is: 30418  value is: 4283054.0  key is: 30453  value is: 8201170.0 </p> <hr/> <p> key is: 30456  value is: 1500491.0  key is: 30457  value is: 90887.0  key is: 30458  value is: 92593.0  key is: 30462  value is: 100994.0  key is: 30468  value is: 88526.0  key is: 30492  value is: 105121.0  key is: 30516  value is: 60665.0  key is: 30522  value is: 899106.0  key is: 30530  value is: 845046.0  key is: 30540  value is: 98749.0  key is: 30547  value is: 479968.0  key is: 30550  value is: 1668191.0  key is: 30552  value is: 43338.0  key is: 30554  value is: 1641384.0  key is: 30569  value is: 83946.0  key is: 30571  value is: 96694.0  key is: 30548  value is: 2294677.0  key is: 30569  value is: 5691670.0 </p> <hr/>
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	<p>The number and the content of data blocks the process accesses</p>	<p>Number of Data Blocks accessed is 4798</p> <p>The content of the top 5 data blocks are:</p> <hr/> <p>This is the data block number: 10989 30 46 65 tt0054166 6.5 15 <b><u>tt0054167 7.7 30022</u></b> tt0054168 5.3 266</p> <hr/> <p>This is the data block number: 3550 30 46 62 tt0026776 6.8 73 tt0026777 6.9 15 <b><u>tt0026778 7.9 30034</u></b></p> <hr/> <p>This is the data block number: 21733 30 49 67 <b><u>tt0091828 5.6 30037</u></b> tt0091829 5.3 4626 tt0091830 7.7 6288</p> <hr/> <p>This is the data block number: 190994 30 49 65 <b><u>tt1456941 6.2 30049</u></b> tt1456944 4.2 62 tt1456946 5.8 8</p> <hr/> <p>This is the data block number: 26940 30 46 65 tt0110441 7.1 23 tt0110442 5.6 24708 <b><u>tt0110443 6.3 30053</u></b></p> <hr/>	<p>Number of Data Blocks accessed is 4032</p> <p>The content of the top 5 data blocks are:</p> <hr/> <p>This is the data block number: 1268 100 119 136 153 169 185 202 218 235 251 269 287 303 319 335 352 367 383 399 416 432 448 466 485 502 518 <b><u>tt0054167 7.7 30022</u></b> tt0054168 5.3 266 tt0054169 5.4 443 tt0054170 5.6 19 tt0054171 7.1 58 tt0054172 5.6 860 tt0054173 5.2 40 tt0054174 6.8 254 tt0054175 6.5 37 tt0054176 7.5 1906 tt0054177 7.2 6095 tt0054178 5.6 41 tt0054179 5.7 11 tt0054180 7.1 10 tt0054181 6.3 165 tt0054182 4.7 9 tt0054183 7.6 73 tt0054184 6.2 16 tt0054185 5.6 100 tt0054186 6.7 65 tt0054187 5.8 93 tt0054188 6.5 3932 tt0054189 7.8 13657 tt0054190 6.6 245 tt0054191 7.0 20 tt0054192 4.8 37</p> <hr/> <p>This is the data block number: 409 100 117 134 149 166 183 198 214 231 246 264 280 296 313 330 347 364 380 396 415 431 448 464 481 497 512 tt0026755 4.9 664 tt0026756 5.5 162 tt0026757 6.4 8 tt0026758 6.6 393 tt0026759 5.5 680 tt0026760 6.8 5 tt0026761 5.9 59 tt0026762 6.9 108 tt0026766 5.7 6 tt0026768 6.7 1168 tt0026769 5.9 57 tt0026771 5.3 25 tt0026772 5.6 266 tt0026773 4.5 146 tt0026774 5.3 207 tt0026775 6.0 204 tt0026776 6.8 73 tt0026777 6.9 15 <b><u>tt0026778 7.9 30034</u></b> tt0026779 5.6 65 tt0026781 6.1 327 tt0026783 6.1 45 tt0026784 6.5 260 tt0026785 5.8 33 tt0026786 5.9 7 tt0026787 6.0 676</p> <hr/> <p>This is the data block number: 2507 100 116 132 150 166 184 201 218 236 254 271 287 304 321 337 353 369 386 405 423 441 457 474 489 506 522 tt0091806 3.5 30 tt0091807 5.2 55 tt0091810 6.2 1554 tt0091813 7.8 21 tt0091814 5.7 4328 tt0091815 5.7 614 tt0091816 6.3 403 tt0091817 7.0 5067 tt0091818 5.7 1499 tt0091819 5.4 214 tt0091820 6.5 99 tt0091821 8.0 280 tt0091823 7.8 974 tt0091824 5.8 69 tt0091825 5.9 89 tt0091826 6.6 25 tt0091827 3.7 589 <b><u>tt0091828 5.6 30037</u></b> tt0091829 5.3 4626 tt0091830 7.7 6288 tt0091831 7.5 12 tt0091832 4.4 282 tt0091833 7.6 7 tt0091834 6.3 425 tt0091835 5.5 31</p>
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			<p>tt0091836 5.3 2121</p> <hr/> <p>This is the data block number: 22041  100 115 131 147 162 177 193 208 223 238  254 270 286 302 319 336 355 371 386 402  418 436 452 468 484 500 tt1456864 6.5 6  tt1456873 5.7 17 tt1456875 4.9 35  tt1456876 6.6 7 tt1456881 7.0 6 tt1456894  7.5 11 tt1456896 5.2 9 tt1456902 5.4 5  tt1456903 8.0 5 tt1456912 5.2 33  tt1456913 6.8 12 tt1456915 5.7 80  tt1456931 7.3 12 tt1456937 6.4 145  tt1456939 6.3 270 <b>tt1456941 6.2 30049</b>  tt1456944 4.2 62 tt1456946 5.8 8  tt1456947 7.4 12 tt1456948 6.2 11  tt1456949 7.2 1706 tt1456950 8.6 39  tt1456953 7.1 17 tt1456957 3.0 56  tt1456958 7.7 10 tt1456961 10.0 5</p> <hr/> <p>This is the data block number: 3108  100 116 135 152 168 185 200 216 232 248  265 283 299 315 334 353 369 385 401 417  434 450 465 481 499 516 tt0110427 7.1 89  tt0110428 7.2 15121 tt0110429 4.8 452  tt0110430 7.2 70 tt0110432 3.5 213  tt0110433 5.2 6 tt0110434 4.4 55 tt0110435  6.8 13 tt0110436 6.7 76 tt0110437 6.6 283  tt0110438 6.5 5493 tt0110440 6.8 32  tt0110441 7.1 23 tt0110442 5.6 24708  <b>tt0110443 6.3 30053</b> tt0110444 5.8 27  tt0110445 7.4 71 tt0110447 6.4 24  tt0110448 8.2 22 tt0110449 7.7 374  tt0110450 8.2 13 tt0110451 9.2 5 tt0110453  7.3 11 tt0110455 6.7 1022 tt0110456 4.8  157 tt0110457 4.6 5</p> <hr/>
	The average of “averageRating”s of the records that are returned	Average of averageRating is: 6.7243775933609955	Average of averageRating is: 6.7243775933609955
5	The number of times that a node is deleted (or two nodes are merged)	Number of nodes deleted/merged is: 3	Number of nodes deleted/merged is: 1
	The number nodes of the	Number of Nodes in the B+ Tree is 330309	Number of Nodes in the B+ Tree is 69298

	updated B+ tree		
	The height of the updated B+ tree	Height after deletion is: 65192	Height after deletion is: 3815
	The content of the root node and its 1st child node of the updated B+ tree	Root node key is: 24 First child contains: 6, 7, 9, 12, 14, 20	Root node key is: 6, 7, 9, 11, 18, 30, 90 First child node contains: 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6

## Contributions

Name	Matriculation Number	Individual Contributions of Team Members
Bachhas Nikita	U1921630F	Report, Installation Guide Code: test1.java test2.java, start1.java, start2.java, Btree.java, LeafNode.java, code compilation, experiments 1, 2, 3, 4
Kam Chin Voon	U1922278G	Report, Installation Guide, Code: test1.java, Btree.java, DictionaryPair.java, Node.java, InternalNode.java, LeafNode.java, experiments 1, 3b, 4c, 4b, 4c, 5
Kundu Koushani	U1922997B	Report