

Analysis of Algorithms

BLG 335E

Project 3 Report

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1. Implementation

1.1. Data Insertion

For the inserat data which given with a csv file, i write the function *csv_to_vector*. *generate_RBT_tree_from_csv* function construct the array and then with the values of array, binary search tree and red-black tree are constructed. For both of them, construction times are calculated. Binary search tree constructed in **104327 microseconds** and red-black tree constructed in **82434 microseconds**. The times shows that red-black tree is little better with random values. But when consider the sorted input, the difference is obvious;

Tree	Random Input	Sorted Input
Binary Search Tree	104327μs	591991μs
Red-Black Tree	82434μs	68415μs

Table 1.1: Construction times of trees for different input forms

The cause of this difference is the red-black tree's self balance operations. In each node insertation red-black tree ensures that the height is $O(\log n)$ but binary search tree goes $O(n)$ in ordered input.

1.2. Search Efficiency

To search with random 50 variable, I write a function *random_50_search*, takes randomly 50 names and search those. Searching function takes $O(\text{height})$ time, it compare the values bigger or lower and according the result, goes to the true side of tree.

To make the measurements more reliable, I took indexes with hand, and I took random index selection loop in the comment paragraph. Average time taken for 50 search for binary search tree is **1442 nanoseconds** , for red-black tree that is **1256 nanosecond**. There is no much difference, but when I make this search with the tree which constructed with ordered input, binary search tree's time spend was **28140 nanoseconds** and red-black tree's time spend was **1172 nanoseconds**. So, the worst case of the binary search tree is much worse because of the height difference, the height of the binary search tree is **573** and height of the red-black tree is **16**.

Tree	Random	Ordered
Binary Search Tree	1442ns	28140ns
Red-Black Tree	1256ns	1172ns

Table 1.2: Search times of trees for different input forms

1.3. Best-Selling Publishers at the End of Each Decade

To calculate the best selling publishers at the end of the decade, I need to access the current cumulative selling values end of the 1990, 2000, etc. I find it in the tree construction part because given years is already in sorted. When I come to the next decade's start, I traverse the tree with preorder traversal, and store the best sellers in the *publisher's* float values.

To print the red-black tree in wanted format, I again use the preorder traversal, but now I also need to hold depth because of the show indentation properly, to make it I push height to the stack with nodes recursively. In every loop I print a line with necessary indentation, node's color and name of the publisher.

1.4. Final Tree Structure

When looking at the final state of the trees, there was a clear difference in height. This difference caused by the red-black tree's balance functions. In all node insertion operation, red-black tree control if there is an unbalance situation between the red and black nodes, it balances the tree with *RB_insert_fixup* function.

The lengths of trees for different inputs are given in the table;

Tree	Random Input	Sorted Input
Binary Search Tree	21	573
Red-Black Tree	11	16

Table 1.3: Heights of trees for different input forms

As shown, binary search tree's height is too much because it is not balance itselfs, then searching and addition operations cost like $O(n)$ instead of $O(\log n)$.

1.5. Write Your Recommendation

A Red-Black Tree is more efficient than a standard Binary Search Tree because it is a self balanced tree, ensuring all operations (insertion, deletion, search) consistently run in $O(\log n)$. In contrast, a Binary Search Tree can degrade to $O(n)$ in the worst case, such as when the input is sorted, making it behave like a linked list.

1.6. Ordered Input Comparison

In ordered input, binary search tree's both addition and updation operations cost $O(n)$, because the given value is always bigger than previous one, that make the tree like a linked-list which add and update time complexity is $O(n)$. But red-black tree balance its height after the each node insertation this balancing operations ensure add and update operations' time complexity keep $O(\log n)$.

In addition, to sort binary search tree, I can use inorder traversal, and I impleement it as function *tree_to_sortedArray_withInorder*. But in my code, I applied a normal sorting in order to compare the randomly given csv with the construction in terms of time.

Operation	Type	Binary Search Tree	Red-Black Tree
Construction	Random	104327μs	82434μs
	Ordered	591991μs	68412μs
Search	Random	1442ns	1256ns
	Ordered	28140ns	1172ns
Height	Random	21	11
	Ordered	573	16

Table 1.4: Efficiency comparison table

Best-Selling Publishers at the End of Each Decade

End of the 1990 Year

Best seller in North America: Nintendo – 160.02 million

Best seller in Europe: Nintendo – 30.03 million

Best seller rest of the World: Nintendo – 5.65 million

End of the 2000 Year

Best seller in North America: Nintendo – 334.75 million

Best seller in Europe: Nintendo – 101.97 million

Best seller rest of the World: Nintendo – 15.76 million

End of the 2010 Year

Best seller in North America: Nintendo – 722.26 million

Best seller in Europe: Nintendo – 350.91 million

Best seller rest of the World: Electronic Arts – 89.2 million

End of the 2020 Year

Best seller in North America: Nintendo – 814.43 million

Best seller in Europe: Nintendo – 418.36 million

Best seller rest of the World: Electronic Arts – 126.82 million

Total time taken for construction: 89435 microseconds

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Preorder print of RBT

(BLACK) Imagic

-(BLACK) Data Age

--(RED) BMG Interactive Entertainment

---(BLACK) Answer Software

----(BLACK) Activision

-----(RED) 989 Studios

------(BLACK) 3DO

------(RED) 20th Century Fox Video Games

------(BLACK) 10TACLE Studios

------(RED) 1C Company

------(BLACK) 2D Boy

------(RED) 5pb
------(BLACK) 505 Games
------(RED) 49Games
------(BLACK) 989 Sports
------(RED) 7G//AMES
------(BLACK) ASCII Entertainment
------(BLACK) ASC Games
------(RED) AQ Interactive
------(RED) Acclaim Entertainment
------(BLACK) ASK
------(RED) ASCII Media Works
------(RED) Abylight
------(BLACK) Ackkstudios
------(RED) Accolade
------(RED) Acquire
------(RED) Agetec
------(BLACK) Adeline Software
------(BLACK) Activision Value
------(RED) Activision Blizzard
------(BLACK) Agatsuma Entertainment
------(RED) Aerosoft
------(BLACK) American Softworks
------(RED) Alchemist
------(BLACK) Aksys Games
------(RED) Alawar Entertainment
------(BLACK) Altron
------(RED) Alternative Software
------(RED) Alvion
------(BLACK) Angel Studios
------(BLACK) Atari
------(RED) ArtDink
------(BLACK) Aques
------(BLACK) Aqua Plus
------(RED) Aria
------(BLACK) Arena Entertainment
------(RED) Arc System Works
------(BLACK) Arika
------(BLACK) Asmik Ace Entertainment
------(RED) Ascaron Entertainment GmbH
------(BLACK) Aruze Corp

------(RED) Ascaron Entertainment
------(BLACK) Asgard
------(RED) Aspyr
------(BLACK) Asmik Corp
------(BLACK) Astragon
------(RED) Asylum Entertainment
------(BLACK) Avalon Interactive
------(BLACK) Atlus
------(RED) Athena
------(RED) Axela
------(BLACK) Avanquest
------(RED) Avanquest Software
------(BLACK) BAM! Entertainment
---(BLACK) CBS Electronics
-----(BLACK) Bethesda Softworks
------(BLACK) Banpresto
------(BLACK) BPS
------(BLACK) Berkeley
------(RED) Benesse
------(BLACK) Blue Byte
------(RED) Black Bean Games
------(BLACK) Big Fish Games
------(RED) Big Ben Interactive
------(RED) Bigben Interactive
------(BLACK) Black Label Games
------(RED) Blast! Entertainment Ltd
------(RED) Brash Entertainment
------(BLACK) Bomb
------(RED) Bohemia Interactive
------(RED) Boost On
------(BLACK) Broccoli
------(RED) BushiRoad
-----(RED) Coleco
------(BLACK) Capcom
------(BLACK) CPG Products
------(BLACK) CCP
------(RED) CDV Software Entertainment
------(BLACK) CTO SpA
------(BLACK) Coconuts Japan
------(RED) ChunSoft

------(BLACK) Cave
------(BLACK) City Interactive
------(RED) Cloud Imperium Games Corporation
------(BLACK) Codemasters Online
------(RED) Codemasters
------(RED) CokeM Interactive
------(BLACK) Crystal Dynamics
------(BLACK) Core Design Ltd.
------(RED) Compile Heart
------(BLACK) Commseed
------(RED) Comfort
------(RED) Compile
------(BLACK) Conspiracy Entertainment
------(BLACK) Creative Core
------(RED) Crave Entertainment
------(RED) Crimson Cow
------(RED) DSI Games
------(BLACK) Culture Publishers
------(BLACK) Culture Brain
------(RED) Crytek
------(RED) D3Publisher
------(BLACK) CyberFront
------(RED) Cygames
------(BLACK) DHM Interactive
------(BLACK) Daedalic
------(BLACK) DTP Entertainment
------(BLACK) Daito
------(RED) Daedalic Entertainment
--(RED) GT Interactive
---(BLACK) Enix Corporation
----(BLACK) Eidos Interactive
------(RED) Disney Interactive Studios
------(BLACK) Datam Polystar
------(BLACK) Data East
------(RED) Data Design Interactive
------(RED) Detn8 Games
------(BLACK) Deep Silver
------(RED) Destineer
------(BLACK) DigiCube
------(RED) Devolver Digital

------(BLACK) DreamWorks Interactive
------(BLACK) DreamCatcher Interactive
------(RED) Dorart
------(RED) ESP
------(BLACK) EA Games
------(RED) Dusenberry Martin Racing
------(RED) EON Digital Entertainment
------(BLACK) Ecole
------(RED) Easy Interactive
------(RED) Edia
------(BLACK) Electronic Arts Victor
------(BLACK) Electronic Arts
------(RED) Elite
------(BLACK) Elf
------(BLACK) Empire Interactive
------(RED) Encore
------(RED) Fortyfive
------(BLACK) Evolution Games
------(BLACK) Epoch
------(BLACK) Enterbrain
------(RED) Enjoy Gaming Ltd.
------(RED) Epic Games
------(BLACK) Essential Games
------(RED) Ertain
------(RED) Flashpoint Games
------(BLACK) Excalibur Publishing
------(BLACK) Evolved Games
------(RED) Falcom Corporation
------(BLACK) Experience Inc.
------(RED) Extreme Entertainment Group
------(BLACK) Fields
------(BLACK) Focus Home Interactive
------(BLACK) Flight-Plan
------(BLACK) Foreign Media Games
------(RED) Focus Multimedia
------(BLACK) FunSoft
------(BLACK) From Software
------(BLACK) Fox Interactive
------(BLACK) FuRyu Corporation
------(RED) FuRyu

------(RED) Fuji
------(BLACK) GN Software
------(RED) Funsta
------(BLACK) Funcom
------(RED) Funbox Media
------(BLACK) G.Rev
------(BLACK) GSP
------(RED) GOA
---(BLACK) HAL Laboratory
----(BLACK) General Entertainment
------(RED) GameTek
------(BLACK) Gainax Network Systems
------(BLACK) Gaga
------(RED) Game Factory
------(BLACK) Gakken
------(BLACK) Game Life
------(RED) GameMill Entertainment
------(BLACK) Gameloft
------(BLACK) Gamebridge
------(RED) Gamecock
------(BLACK) Gathering of Developers
------(RED) Games Workshop
------(RED) Gearbox Software
------(RED) Gotham Games
------(BLACK) Glams
------(RED) Genterprise
------(BLACK) Genki
------(BLACK) Giga
------(RED) Ghostlight
------(RED) Giza10
------(BLACK) Global Star
------(RED) Global A Entertainment
------(BLACK) Gremlin Interactive Ltd
------(BLACK) Grand Prix Games
------(RED) Graffiti
------(RED) Graphsim Entertainment
------(RED) GungHo
------(BLACK) Groove Games
------(RED) Griffin International
------(BLACK) Gust

-----(BLACK) Hudson Soft
------(RED) Hearty Robin
------(BLACK) Hasbro Interactive
------(RED) Hackberry
------(BLACK) HMH Interactive
------(BLACK) Happinet
------(RED) Hamster Corporation
------(RED) Harmonix Music Systems
------(BLACK) Havas Interactive
------(RED) Headup Games
------(BLACK) Hip Interactive
------(BLACK) Hello Games
------(RED) Hect
------(RED) Her Interactive
------(BLACK) Hudson Entertainment
------(RED) Home Entertainment Suppliers
------(BLACK) Ignition Entertainment
------(RED) ITT Family Games
------(BLACK) HuneX
------(RED) Human Entertainment
------(RED) IE Institute
------(BLACK) Idea Factory
------(RED) Iceberg Interactive
------(RED) Idea Factory International
------(RED) Imadio
------(BLACK) Illusion Softworks
------(BLACK) Imageworks
------(RED) Image Epoch
--(BLACK) Quelle
--(RED) Mattel Interactive
---(BLACK) Kemco
-----(BLACK) Interplay
------(BLACK) Imax
------(BLACK) Imagineer
------(RED) Infogrames
------(BLACK) Indie Games
------(BLACK) Interchannel
------(RED) Insomniac Games
------(RED) Interchannel-Holon
------(RED) Jorudan

------(BLACK) Jaleco
------(RED) Irem Software Engineering
------(BLACK) Inti Creates
------(RED) Interplay Productions
------(RED) Introversion Software
------(BLACK) JVC
------(RED) Ivolgamus
------(RED) Jack of All Games
------(BLACK) Jester Interactive
------(RED) JoWood Productions
------(BLACK) KSS
------(BLACK) KID
------(RED) Just Flight
------(RED) Kalypso Media
------(BLACK) Kadokawa Shoten
------(RED) Kadokawa Games
------(RED) Kaga Create
------(BLACK) Kando Games
------(RED) Kamui
------(RED) Karin Entertainment
-----(BLACK) MTO
-----(RED) Laguna
------(BLACK) Konami Digital Entertainment
------(RED) Knowledge Adventure
------(BLACK) King Records
------(RED) Kids Station
------(BLACK) Kokopeli Digital Studios
------(RED) Koch Media
------(BLACK) LEGO Media
------(RED) Kool Kizz
------(RED) LSP Games
------(BLACK) Lighthouse Interactive
------(RED) Level 5
------(BLACK) Legacy Interactive
------(BLACK) Lexicon Entertainment
------(RED) Licensed 4U
------(RED) Locus
------(BLACK) Liquid Games
------(RED) Little Orbit
------(BLACK) MC2 Entertainment

------(RED) LucasArts
------(RED) MLB.com
------(BLACK) Mamba Games
------(RED) Magix
------(BLACK) Mad Catz
------(RED) MTV Games
------(RED) Magical Company
------(BLACK) Majesco Entertainment
------(RED) Marvelous Interactive
------(BLACK) Marvelous Entertainment
------(RED) Marvel Entertainment
------(RED) Marvelous Games
------(BLACK) Mastertronic
------(RED) Masque Publishing
------(RED) Mastiff
---(BLACK) Mystique
-----(BLACK) Microprose
------(RED) Men-A-Vision
------(BLACK) Media Rings
------(RED) Maxis
------(BLACK) Max Five
------(RED) Maximum Family Games
------(BLACK) Media Factory
------(BLACK) MediaQuest
------(RED) Media Works
------(BLACK) Micro Cabin
------(RED) Metro 3D
------(BLACK) Mercury Games
------(RED) Mentor Interactive
------(RED) Merscom LLC
------(BLACK) Michaelsoft
------(BLACK) Microids
-----(RED) Misawa
------(BLACK) Midway Games
------(BLACK) Microsoft Game Studios
------(RED) Midas Interactive Entertainment
------(RED) Minato Station
------(BLACK) Milestone S.r.l.
------(RED) Milestone
------(RED) Milestone S.r.l.

------(BLACK) Mindscape
------(RED) Mirai Shounen
------(BLACK) Mud Duck Productions
------(RED) Monte Christo Multimedia
------(BLACK) Mitsui
------(RED) Mojang
------(BLACK) Moss
------(BLACK) Mycom
------(RED) Mumbo Jumbo
------(RED) Myelin Media
-----(RED) Origin Systems
------(BLACK) Nintendo
------(RED) Namco Bandai Games
------(BLACK) NEC
------(BLACK) NCSOFT
------(RED) NCS
------(RED) NDA Productions
------(BLACK) NEC Interchannel
------(BLACK) New
------(RED) Navarre Corp
------(BLACK) Natsume
------(BLACK) Neko Entertainment
------(RED) Naxat Soft
------(RED) NetRevo
------(RED) NewKidCo
------(BLACK) New World Computing
------(BLACK) Nichibutsu
------(RED) Nexon
------(RED) Nihon Falcom Corporation
------(RED) NovaLogic
------(BLACK) Nippon Ichi Software
------(BLACK) Nippon Amuse
------(RED) Nippon Columbia
------(RED) Nobilis
------(BLACK) Nippon Telenet
------(RED) Nitroplus
------(BLACK) Nordcurrent
------(RED) Nordic Games
------(BLACK) Ocean
------(BLACK) O-Games

------(RED) Number None
------(RED) O3 Entertainment
------(BLACK) On Demand
------(RED) Office Create
------(RED) Ongakukan
------(BLACK) Parker Bros.
------(RED) Pack In Soft
------(BLACK) PQube
------(RED) P2 Games
------(BLACK) Oxygen Interactive
------(RED) Otomate
------(BLACK) PM Studios
------(BLACK) Pacific Century Cyber Works
------(BLACK) Palcom
------(BLACK) Pack-In-Video
------(RED) Paon
------(BLACK) Panther Software
------(BLACK) Paradox Development
------(RED) Paon Corporation
------(RED) Paradox Interactive
------(RED) Playmates
------(BLACK) Pioneer LDC
------(RED) Phenomedia
------(BLACK) Phantagram
------(RED) Performance Designed Products
------(RED) Phantom EFX
------(BLACK) Piacci
------(RED) Phoenix Games
------(RED) Pinnacle
------(BLACK) PlayV
------(RED) Play It
------(RED) Playlogic Game Factory
------(BLACK) Pow
------(RED) Pony Canyon
------(BLACK) Playmore
------(RED) Plenty
------(BLACK) PopTop Software
------(RED) PopCap Games
------(RED) Popcorn Arcade
------(BLACK) Prototype

------(RED) Princess Soft
------(RED) Psygnosis
--(RED) Starpath Corp.
---(BLACK) Sonnet
----(RED) Russel
------(BLACK) Red Orb
------(BLACK) Quintet
------(BLACK) Quest
------(RED) Quinrose
------(RED) Rage Software
------(BLACK) RTL
------(RED) RED Entertainment
------(BLACK) Rebellion Developments
------(RED) Rebellion
------(RED) Red Flagship
------(BLACK) Revolution (Japan)
------(RED) RedOctane
------(BLACK) Red Storm Entertainment
------(BLACK) Reef Entertainment
------(RED) Riverhillsoft
------(BLACK) Rising Star Games
------(RED) Revolution Software
------(BLACK) Rocket Company
------(RED) Rondomedia
-----(BLACK) Sammy Corporation
------(BLACK) SNK
------(BLACK) SCi
------(RED) SCS Software
------(BLACK) SPS
------(RED) SNK Playmore
------(RED) SSI
------(RED) Seta Corporation
------(BLACK) Scholastic Inc.
------(BLACK) Saurus
------(BLACK) Sega
------(RED) Screenlife
------(BLACK) Simon & Schuster Interactive
------(BLACK) Shogakukan
------(RED) Seventh Chord
------(RED) Slitherine Software

------(BLACK) Slightly Mad Studios
------(BLACK) Societa
------(RED) Sold Out
-----(BLACK) Square
------(BLACK) Sony Computer Entertainment Europe
------(BLACK) Sony Computer Entertainment
------(RED) Sony Computer Entertainment America
------(RED) SouthPeak Games
------(BLACK) Sony Music Entertainment
------(RED) Sony Online Entertainment
------(BLACK) Spike
------(BLACK) SquareSoft
------(BLACK) Square Enix
------(RED) Square EA
------(RED) Square Enix
------(BLACK) Starfish
------(RED) Stainless Games
---(BLACK) Tigervision
-----(BLACK) Takara
------(RED) T&E Soft
------(BLACK) Sunsoft
------(RED) Success
------(BLACK) Storm City Games
------(RED) Sting
------(RED) Strategy First
------(BLACK) Sunflowers
------(RED) Summitsoft
------(RED) Sunrise Interactive
------(RED) Syscom
------(BLACK) Swing! Entertainment
------(RED) Sweets
------(BLACK) System 3 Arcade Software
------(RED) System 3
------(RED) System Soft
------(BLACK) TOHO
------(RED) TDK Mediactive
------(BLACK) TDK Core
------(BLACK) THQ
------(RED) TGL
------(BLACK) Taito

------(RED) TYO
------(RED) Tecmo Koei
------(BLACK) TechnoSoft
------(RED) Take-Two Interactive
------(BLACK) Takara Tomy
------(BLACK) TalonSoft
------(RED) Takuyo
------(RED) Team17 Software
------(BLACK) Technos Japan Corporation
------(BLACK) Telstar
------(BLACK) Telegames
------(RED) Telltale Games
------(BLACK) The Adventure Company
------(RED) Tetris Online
------(RED) The Learning Company
-----(RED) Victor Interactive
------(BLACK) U.S. Gold
------(RED) Tomy Corporation
------(BLACK) Titus
------(BLACK) Time Warner Interactive
------(BLACK) Tommo
------(RED) Tivola
------(BLACK) Tradewest
------(BLACK) Touchstone
------(RED) TopWare Interactive
------(RED) Tripwire Interactive
------(BLACK) Trion Worlds
------(BLACK) Tryfirst
------(RED) Tru Blu Entertainment
------(RED) Type-Moon
------(RED) ValuSoft
------(BLACK) Universal Gamex
------(RED) UFO Interactive
------(BLACK) UEP Systems
------(BLACK) Ubisoft
------(RED) UIG Entertainment
------(RED) Ubisoft Annecy
------(BLACK) Universal Interactive
------(RED) Valcon Games
------(BLACK) Vatical Entertainment

------(BLACK) Valve Software
------(RED) Valve
------(RED) Vap
------(BLACK) Vic Tokai
------(BLACK) Yumedia
------(RED) Wizard Video Games
------(BLACK) Wanadoo
------(RED) Virgin Interactive
------(BLACK) Views
------(RED) Video System
------(RED) Vir2L Studios
------(BLACK) Visco
------(RED) Virtual Play Games
------(RED) Vivendi Games
------(RED) Warp
------(BLACK) Wargaming.net
------(RED) Warashi
------(RED) Warner Bros. Interactive Entertainment
------(BLACK) Westwood Studios
------(RED) WayForward Technologies
------(RED) White Park Bay Software
------(BLACK) Xplosiv
------(RED) Xicat Interactive
------(BLACK) XS Games
------(BLACK) Xing Entertainment
------(RED) Yeti
------(BLACK) Yacht Club Games
------(RED) Xseed Games
------(RED) Yamasa Entertainment
------(BLACK) Yuke's
------(RED) Zushi Games
------(BLACK) Zoo Digital Publishing
------(BLACK) Zenrin
------(BLACK) Zoo Games
------(BLACK) id Software
------(RED) fonfun
------(BLACK) bitComposer Games
------(RED) dramatic create
------(BLACK) iWin
------(BLACK) inXile Entertainment

------(RED) imageepoch Inc.

------(RED) responDESIGN

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