

Artificial Intelligence Capstone

NYCU - Spring 2025

Before we actually start the course, let's chat about some developments in "AI":

StyleGAN (nVidia, 2018/12)



Are these real people?

<https://petapixel.com/2017/11/07/ai-creates-photo-realistic-faces-people-dont-exist/>

<https://www.thispersondoesnotexist.com/>

Some improvements. Can you see the difference?

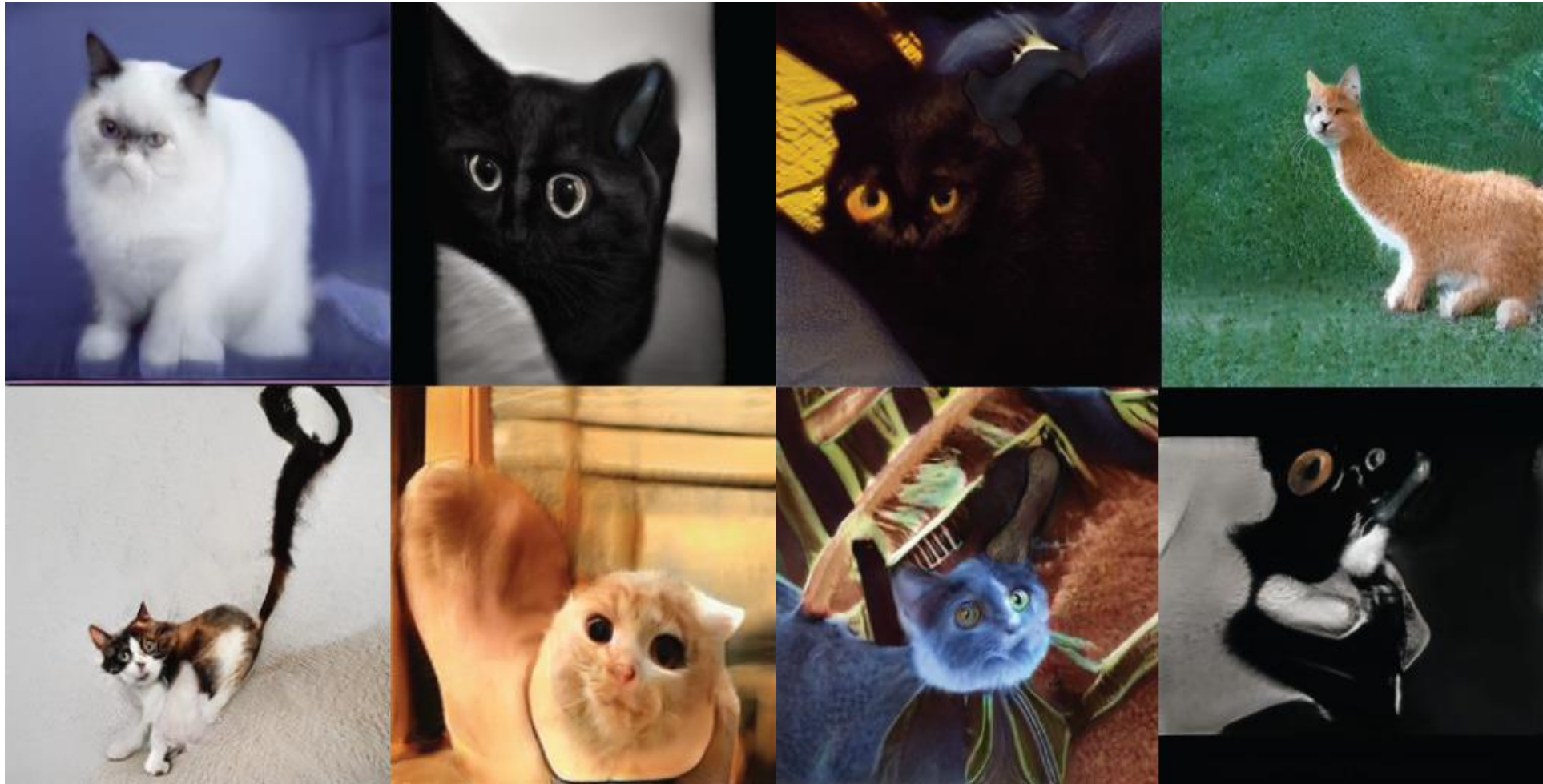
StyleGAN2 (nVidia, 2019/12)



Do you see any problem?

<https://www.thispersondoesnotexist.com/>

StyleGAN applied to cats (nVidia, 2019/2)



Are these real cats?

StyleGAN2 applied to cats (2022/01)



How do you feel about the improvements here?

<https://thecatsexist.com/>

StyleGAN2 applied to cats (2022/01)

From yet another cat website:



Any better (more like real cats)? Why?

<https://thiscatdoesnotexist.com/>

Cats by DALL-E 2 (OpenAI, 2022)

w/ keyword
"photo"



w/ keyword
"photo realistic"



Cats by DALL-E 3 (OpenAI, 2023/10)

w/ keyword "photographic walking"



How do you like these state-of-the-art cats?

"Happy Cat" by SORA (OpenAI, 2024/2)



OK, enough about cats.

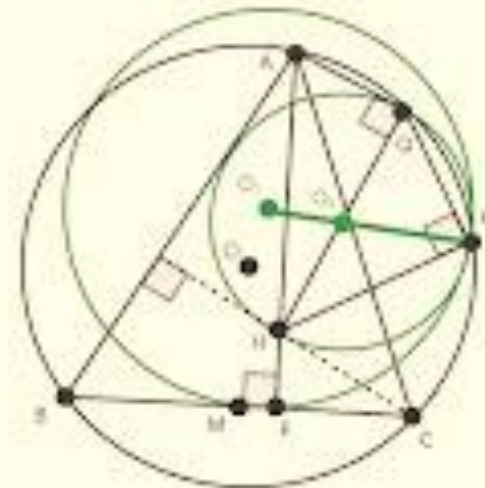
Some other news: AlphaGeometry (DeepMind, 2024/1)

Well, we should not forget about the group that created AlphaGo...

This system claims to solve geometry proof problems at the level of gold medalists of International Mathematics Olympiad.

IMO 2015 P3

Let ABC be an acute triangle. Let (O) be its circumcircle, H its orthocenter, and F the foot of the altitude from A . Let M be the midpoint of BC . Let Q be the point on (O) such that $QH \perp QA$ and let K be the point on (O) such that $KH \perp KQ$. Prove that the circumcircles (O_1) and (O_2) of triangles FKM and KQH are tangent to each other.



Nobel Prize 2024 – Physics

John J. Hopfield

“for foundational discoveries and inventions that enable machine learning with artificial neural networks”



Geoffrey Hinton

“for foundational discoveries and inventions that enable machine learning with artificial neural networks”



Nobel Prize 2024 – Chemistry

David Baker

“for computational protein design”



Demis Hassabis

“for protein structure prediction”



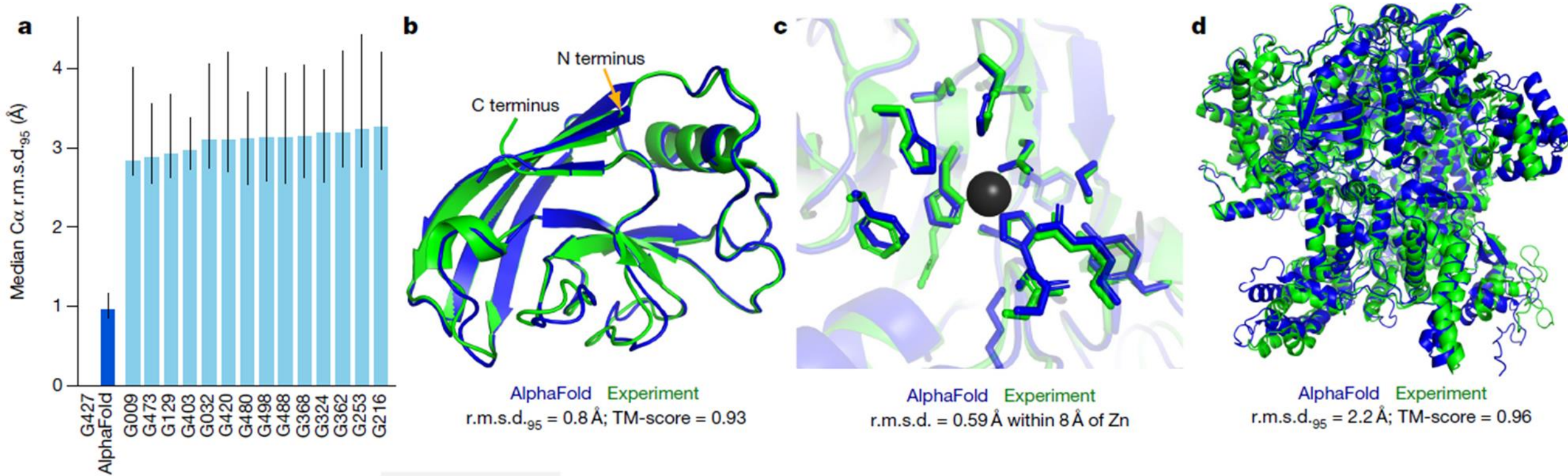
John Jumper

“for protein structure prediction”



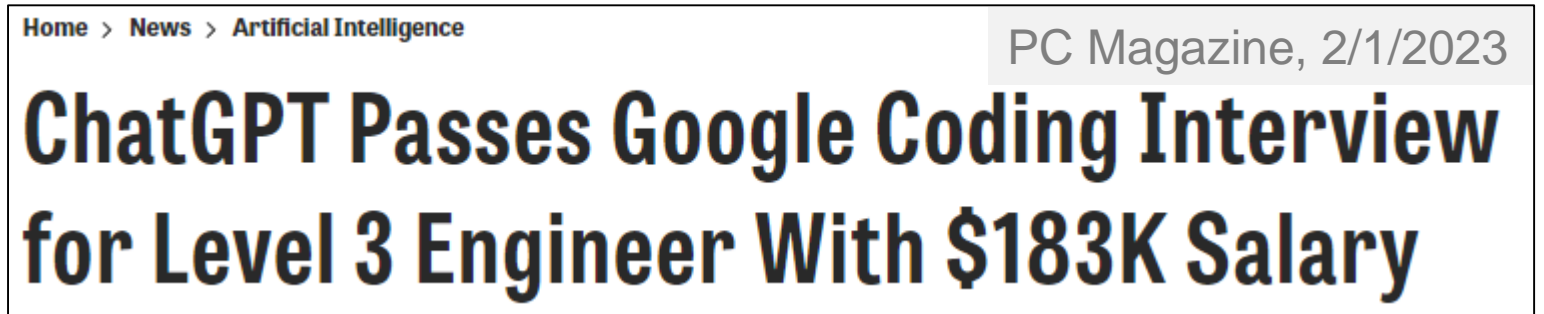
AlphaFold2

This is something that is likely to revolutionize a whole field and affect our lives.



Some Thoughts about AI

- Have you tried ChatGPT (or anything similar)? For what?
- If ChatGPT can write programs, what should you do as a CS major (if you are one)?



- Your definition of AGI (artificial general intelligence)?
- What do you want AI to do for you?
- What are human's roles (and your role) in the age of AI?

Really, How Smart (or Not) are Today's AI?

I happen to test this task on several models recently:

把 10, 20, 30, 15, 25, 35, 45, 12, 22, 32
這幾個數字按順序加入紅黑樹

GPT-4o (1/2)

把 10,20,30,15,25,35,45,12,22,32這幾個數字按順序加入紅黑樹

讓我們將數字 10, 20, 30, 15, 25, 35, 45, 12, 22, 32 按順序插入紅黑樹，並確保每一步都正確。以下是插入過程及最終結構：

插入步驟

插入 10

10 成為根節點，顏色設為黑色。

插入 20

20 作為 10 的右子節點，顏色設為紅色。

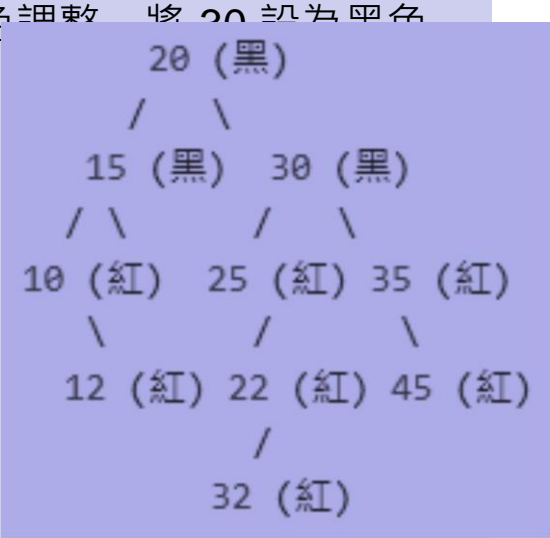
32 作為 30 的左子節點，顏色設為紅色。

這時 30 和 32 都是紅色，進行顏色調整，將 20 設為黑色，並進行旋轉。

...

最終結構

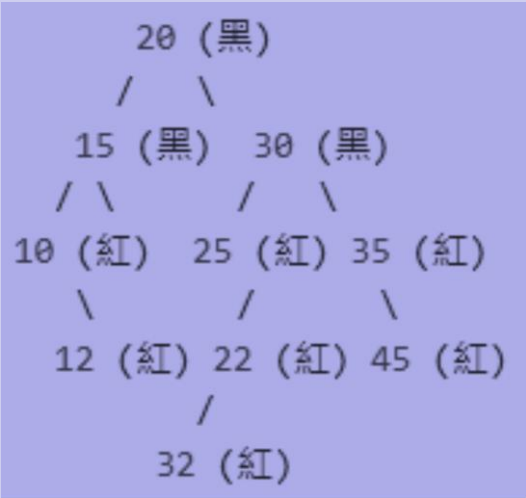
最終的紅黑樹結構應該如下所示：



這樣的結構滿足紅黑樹的所有性質。如果還有其他問題或需要進一步的解釋，請告訴我！

node 32的位置有問題

感謝你的指正！讓我們重新檢查並修正節點 32 的位置。修正後的紅黑樹結構



說明

節點 32 應該是 22 的左子節點。
如果還有其他問題，請隨時告訴我！

GPT-4o (2/2)

The position of node 32 is still wrong. And this does not satisfy red-black tree condition.

Thank you for your patience. Let's carefully reconstruct the red-black tree with the correct structure and ensure it satisfies all the red-black tree properties.

Insertion Steps Recap

We will insert the numbers 10, 20, 30, 15, 25, 35, 45, 12, 22, 32 in order and maintain the red-black tree properties.

Insert 10:

Root: 10 (Black)

Insert 20:

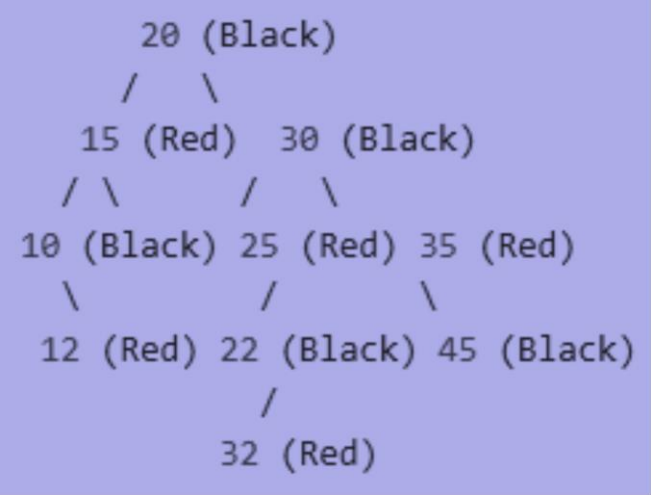
20 is added as the right child of 10 (Red).

...

Insert 32:

32 is added as the left child of 35 (Red).

35 and 32 are both Red; perform rotations and color flips



Correct Final Structure

After ensuring all properties are satisfied, the correct structure should be:

Gemini 2.0 Pro (1/1)

把 10,20,30,15,25,35,45,12,22,32 這幾個數字按順序加入紅黑樹

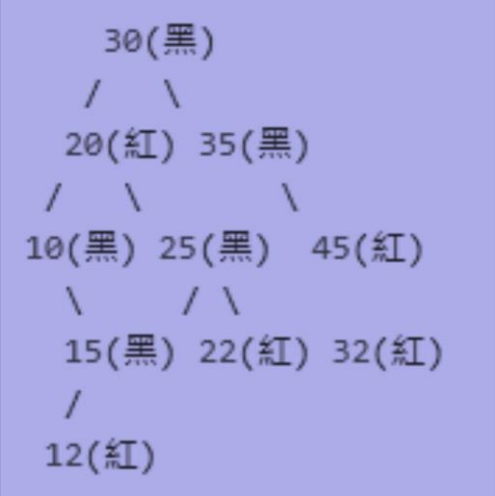
好的，我們將依序把這些數字加入紅黑樹，並以圖形方式呈現每一步驟。

初始狀態：空樹

步驟 1：加入 10

...

最終的紅黑樹：



請注意，以上為文字描述的紅黑樹結構。在實際應用中，紅黑樹的插入操作會涉及更複雜的旋轉和重新著色，以確保樹的平衡。

Which node is the parent of node 32?

節點 35 是節點 32 的父節點。

Please redraw the tree so that the parent of node 32 is node 35

好的，您說的沒錯，35 應該是 32 的父節點。我先前的步驟描述在最後幾步有些跳躍，導致最終結構有誤。以下是修正後的步驟和最終正確的紅黑樹結構：

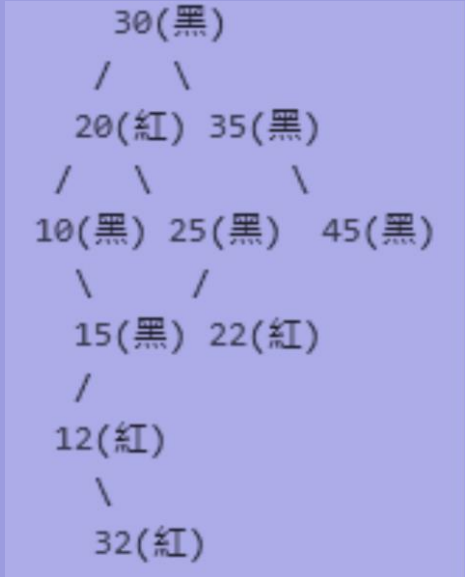
重新審視步驟 9 (加入 22):

...

步驟 10 (加入 32):

...

最終的紅黑樹 (正確版):



現在，32 的父節點正確地為 35。非常抱歉之前的錯誤！

Claude 3.5 Sonnet V2 (1/3)

把 10,20,30,15,25,35,45,12,22,32 這幾個數字按順序加入紅黑樹

我會協助你將這些數字依序加入紅黑樹中。讓我們一步一步來看樹的變化。

初始紅黑樹為空，我們依序加入：10, 20, 30, 15, 25, 35, 45, 12, 22, 32

插入過程說明：

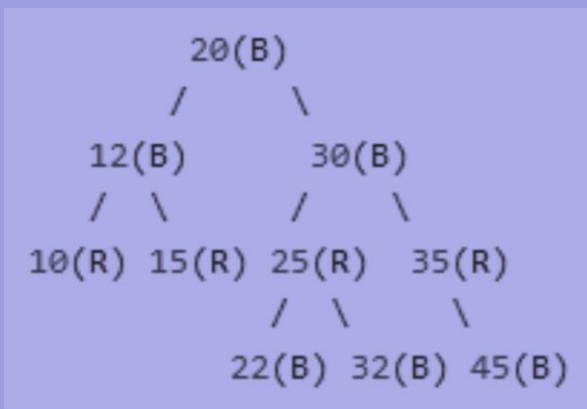
插入 10：作為根節點，設為黑色

插入 20：作為 10 的右子節點，設為紅色

...

插入 32：最後一個節點的插入和平衡

最終的紅黑樹結構大致如下（B代表黑色節點，R代表紅色節點）：



There is an error when inserting node 32 (step 10)

抱歉我的錯誤。讓我重新分析插入 32 時的情況。

讓我們重新檢查最後幾個步驟：

在插入 32 之前的樹結構是：

...

當插入 32 時：

32 會被插入為 30 右子樹中的節點

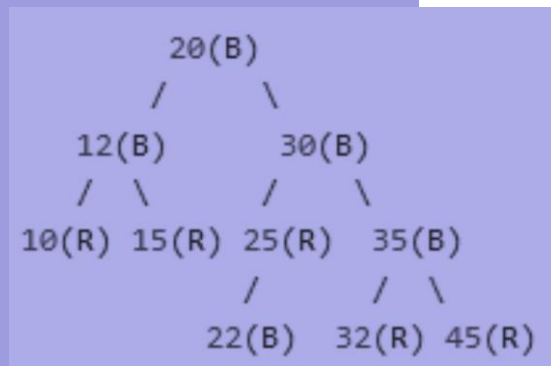
初始時 32 是紅色

32 應該要作為 35 的左子節點

這會造成兩個連續的紅色節點（30-35-32），違反紅黑樹性質

需要進行顏色調整和旋轉操作

修正後的最終紅黑樹結構應該是：



這樣的結構才能確保：

...

不會有兩個連續的紅色節點

所有路徑上的黑色節點數量相同

樹依然保持平衡

感謝您指出這個錯誤，這個修正後的結構才是正確的紅黑樹。

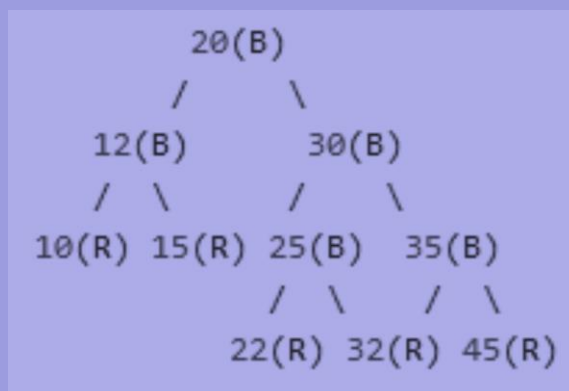
Claude 3.5 Sonnet V2 (2/3)

This tree does not satisfy the second condition (equal number of black nodes along all paths)

您說得對，我再次檢查，發現我的樹結構確實違反了紅黑樹的性質：從根節點到所有葉節點的路徑必須包含相同數量的黑色節點。

讓我重新分析插入 32 的過程：

...
正確的最終紅黑樹結構應該是：



現在這個結構滿足所有紅黑樹的性質：

每個節點要麼是紅色要麼是黑色

根節點是黑色

所有葉節點 (NIL, 圖中未畫出) 都是黑色

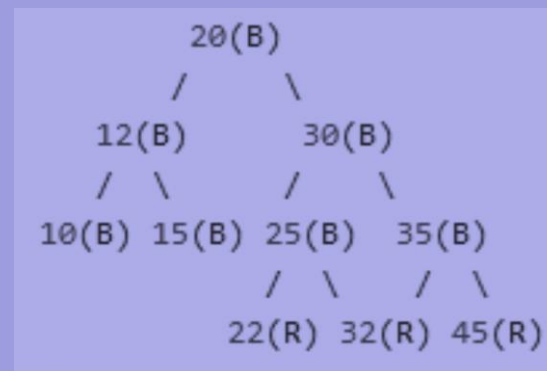
如果一個節點是紅色，則其子節點都是黑色

從任一節點到其每個葉節點的所有路徑都包含相同數目的黑色節點
(在這個樹中，從根到任何葉節點都是3個黑色節點)

感謝您的指正，這個修正後的結構才是真正符合紅黑樹所有性質的正確結構。

The leftmost path (root to node 10) has only two black nodes

您說得對，我又犯了一個錯誤。讓我再次仔細檢查並修正。插入 32 並進行必要的平衡和顏色調整後，正確的最終紅黑樹結構應該是：



現在這個結構真正滿足所有紅黑樹的性質：

...

從任一節點到其每個葉節點的所有路徑都包含相同數目的黑色節點

從根到10：20(B) -> 12(B) -> 10(B) = 3個黑節點

從根到15：20(B) -> 12(B) -> 15(B) = 3個黑節點

從根到22：20(B) -> 30(B) -> 25(B) -> 22(R) = 3個黑節點

從根到32：20(B) -> 30(B) -> 25(B) -> 32(R) = 3個黑節點

從根到45：20(B) -> 30(B) -> 35(B) -> 45(R) = 3個黑節點

感謝您的耐心指出錯誤，這個版本才是真正符合所有紅黑樹性質的正確結構。

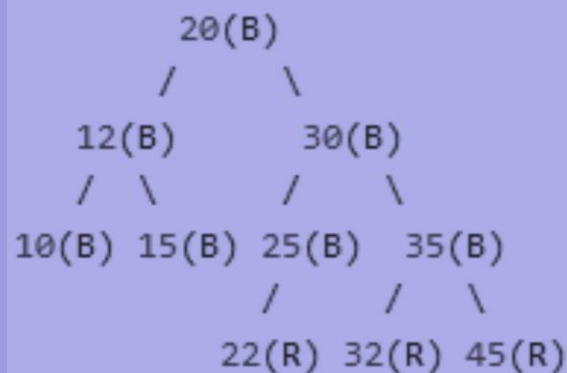
Claude 3.5 Sonnet V2 (3/3)

But the parent of node 32 is still incorrect

啊！您說得對。我需要再次修正。

讓我重新檢查 32 的位置。32 比 30 大但比 35 小，所以應該要是 35 的左子節點，而不是 25 的右子節點。

正確的最終紅黑樹結構應該是：



現在這個結構真正滿足所有紅黑樹的性質：

...

從根到10：20(B) -> 12(B) -> 10(B) = 3個黑節點

從根到15：20(B) -> 12(B) -> 15(B) = 3個黑節點

從根到22：20(B) -> 30(B) -> 25(B) -> 22(R) = 3個黑節點

從根到32：20(B) -> 30(B) -> 35(B) -> 32(R) = 3個黑節點

從根到45：20(B) -> 30(B) -> 35(B) -> 45(R) = 3個黑節點

感謝您的持續指正，這次的結構才是真正正確的紅黑樹，32 的位置也正確了。

DeepSeek R1(1/2)

把 10,20,30,15,25,35,45,12,22,32這幾個數字按順序加入紅黑樹

思考 57 秒

思考過程

好的，現在需要解決用戶的問題，也就是把一系列數字按照順序插入紅黑樹中。首先，我得回想一下紅黑樹的基本規則和插入操作的步驟。用戶提供的數字是10,20,30,15,25,35,45,12,22,32，需要按順序插入。

... (about 500 words skipped)

以下是將數字10,20,30,15,25,35,45,12,22,32依序插入紅黑樹的過程分析：

[逐步插入過程]

...
後續插入12,22,32時，會根據位置觸發：
顏色翻轉（當父叔皆紅時）
左旋/右旋調整（形成連續紅節點時）
最終保持黑高度平衡

[Python實現要點]

...
完整實作需包含：

...
紅黑樹通過這些調整保持近似平衡，確保操作時間複雜度維持在 $O(\log n)$ 等級。實際插入時需注意父節點指針的維護與NIL節點的處理。

What is the final tree then?

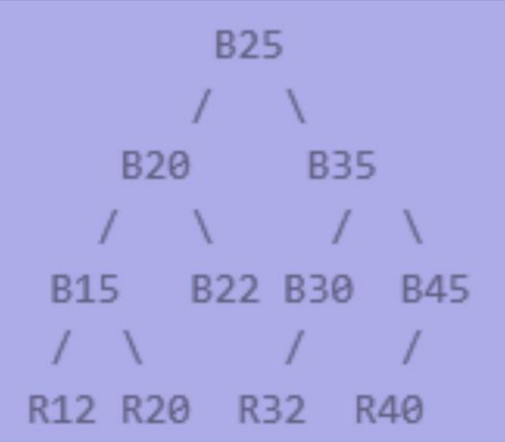
思考 42 秒

思考過程

好的，我需要解決使用者詢問將特定數字序列插入紅黑樹後的最終結構問題。首先，我需要回憶紅黑樹的基本規則和插入過程。

... (about 500 words skipped)

根據插入順序調整後，最終紅黑樹結構如下：



[結構特徵分析]

...
此結構通過多次旋轉與顏色翻轉保持平衡，確保查詢效率維持在 $O(\log n)$ 級別。實際Python實作時需注意每次插入後的平衡檢查與指針更新。

DeepSeek R1(2/2)

There is something wrong with the tree drawn. Please redraw.

思考 66 秒
思考過程

好的，用户指出我画的树有问题，需要重新绘制。首先，我需要仔细检查之前的回答中的红黑树结构是否存在错误。

用户插入的顺序是10,20,30,15,25,35,45,12,22,32。但根据这个插入顺序，最后插入的节点应该是32，而我的树中却出现了40这个节点，这显然是一个错误。用户并没有插入40，所以这里多了一个不存在的节点，需要纠正。

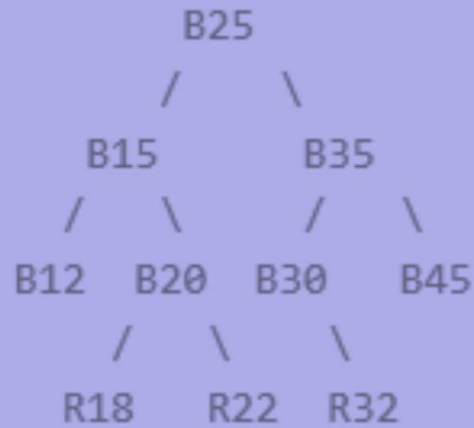
接下来，我需要重新构建正确的红黑树结构。让我逐步分析每个插入步骤，确保每个节点的位置和颜色正确。

插入顺序：10,20,30,15,25,35,45,12,22,32

插入10（根节点，变为黑色）

...

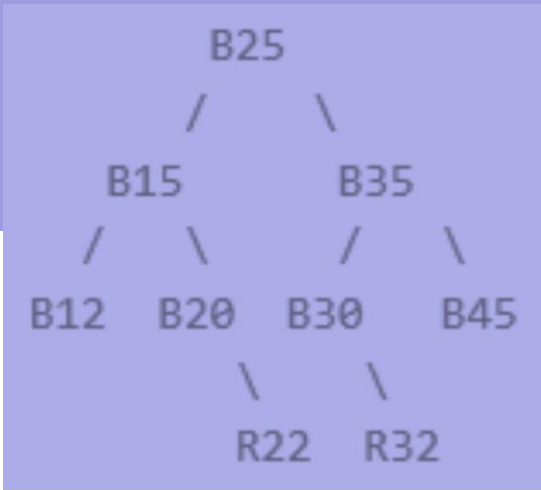
讓我們重新建構正確的紅黑樹結構，插入順序為10,20,30,15,25,35,45,12,22,32：



where does node 18 come from?

思考 7 秒
思考過程

您的觀察非常正確，這是一個需要修正的錯誤。原插入序列中並不存在數值18的節點，這是由於我之前在繪製結構時出現了筆誤。讓我們重新建構正確的紅黑樹結構（插入順序：10,20,30,15,25,35,45,12,22,32）：



Really, How Smart (or Not) are Today's AI?

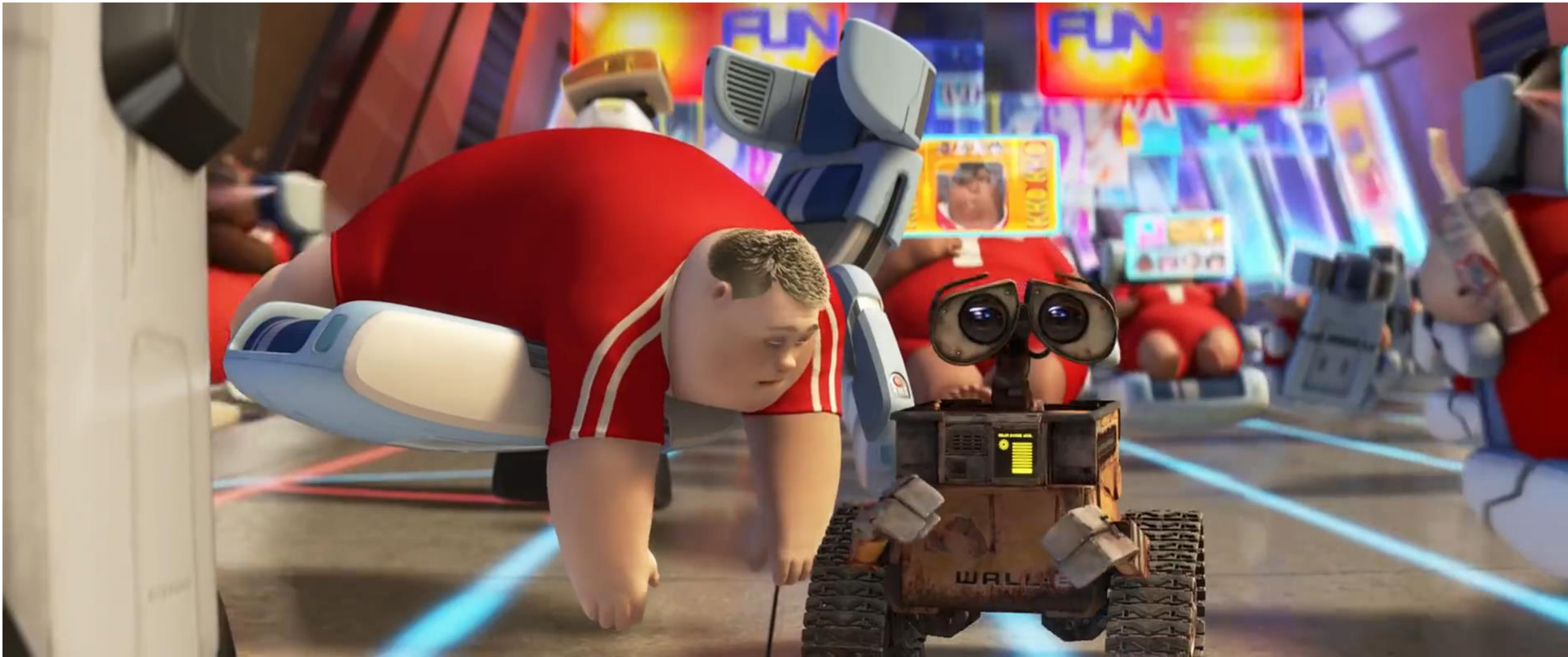
So what do we learn from this experiment?

Have you ever seen this picture?



What defines "creativity"?

Ever Seen This 2008 Movie?



What's in your mind when you see this?

About This Course

■ What is a **Capstone** course, anyway?

- Integration of Knowledge: Students synthesize and apply concepts, theories, and skills learned in their major or field of study.
- Project-Based Learning: Often involves a significant project, such as a research paper, presentation, portfolio, or real-world problem-solving task.
- Collaboration: May require teamwork or partnerships with peers, faculty, or external organizations.
- Practical Application: Focuses on solving real-world problems or addressing current issues in the field.
- Assessment of Readiness: Serves as a way for students to demonstrate their preparedness for professional work or further academic pursuits.

(Answer by GPT-4o w/ RAG)

Basic Course Information

- Instructor information:
 - Contact: EC709, ext. 56689, wangts@cs.nycu.edu.tw
 - Office hour: By appointment
- Class time is 1:20-3:10pm on Mondays only.
- There is no required textbook. Extra readings might be provided from time to time in addition to the lecture material.
- This is an English-Medium Course. However, you can still ask questions in Chinese. Your written reports can be in English or Chinese, but oral and poster presentations have to be in English.
- Programming language allowed: C++ and Python.

Course Prerequisites

- You need to be good at programming. This course requires substantial hands-on implementation and experiments.
- Good knowledge of data structures and algorithms.
- Knowledge from previous courses: Introduction to Artificial Intelligence and Introduction to Machine Learning. We will have quick reviews, not detailed discussions.

The Lectures

- There will still be lectures, even though lectures are not the essential part of a capstone course.
- A few planned and possible lecture topics:
 - A quick overview of supervised learning, for first project
 - Unsupervised and self-supervised learning
 - Reinforcement learning and game-playing agents
 - Natural language processing basics
 - Meta-heuristics (genetic algorithms, swarm intelligence, etc.)
 - TBD

Course Requirements and Grading

- Project #1 (individual): Experiments with supervised learning, including building your own datasets.
 - Code, dataset, and written report.
- Project #2 (individual): An experiment on reinforcement learning.
 - Code, written report, demo video.
- Project #3 (group of 1-3):
 - One of several topical fields.
 - Meetings with the instructor: Proposal and checkpoint.
 - Final demo / presentation / poster contest.
 - Proposal, written report.
- A short essay on an AI related societal/cultural/legal/etc. topic.
- Exam (on lecture material)

Guidelines of Assignments

- You are free to use existing libraries or codes on the web. Just clearly specify the source if you do.
- You can use AI tools to help with your reports and/or coding. Just clearly specify in your report.
- You can discuss with each other, but each assignment should be done individually, or only by a group if it's a group project.

Temporary Schedule

- W1: Introduction
- W2-4: Lectures
- W5: Project #1 due
- W5-7: Invited lectures on topic areas of Project #3
- W8-9: Lectures
- W10: Project #2 due
- W10-11: Project #3 proposal meetings
- W12: No class
- W13-14: Project #3 checkpoint meetings
- W15: Exam
- W16: Project #3 Poster Presentation / Contest
- W17: Project #3 report due