

파이썬으로 배우는 데이터 구조



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학습 목표

Big-O 표기법이 무엇인지 알고 직접 계산할 수 있다

Data Structures in Python

Chapter 2 - 2

- Performance Analysis
- **Big-O Notation**
- Big-O Properties
- Growth Rates
- Growth Rates Examples

그러므로 나의 사랑하는 자들아 너희가 나 있을 때 뿐 아니라 더욱 지금 나 없을 때에도 항상 복종하여 두렵고 떨림으로 너희 구원을 이루라 (Continue to work out your salvation with fear and trembling.) 빌2:12

나는 인애를 원하고 제사를 원하지 아니하며 번제보다 하나님을 아는 것을 원하노라 (호6:6)
하나님은 모든 사람이 구원을 받으며 진리를 아는데에 이르기를 원하시느니라 (딤후2:4)

그런즉 너희가 먹든지 마시든지 무엇을 하든지 다 하나님의 영광을 위하여 하라 (고전10:31)

Agenda & Reading

- **Big-O Notation**
 - **Asymptotic Analysis**
- **Big-O Properties**
 - **Calculating Big-O**

- **References:**
 - Textbook: Problem Solving with Algorithms and Data Structures
 - Chapter 3. [Analysis](#)
 - Textbook: www.github.idebtor/DSPy
 - Chapter 2.1 ~ 3

3 Big-O Definition

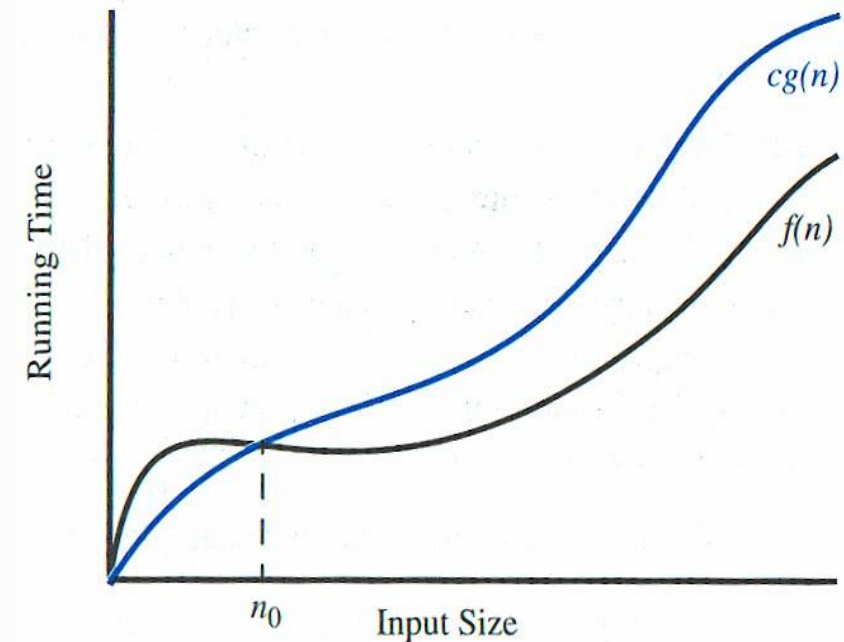
- Let $f(n)$ and $g(n)$ be functions that map non-negative integers to real numbers. We say that **$f(n)$ is $O(g(n))$** if there is a real constant c , where $c > 0$ and an integer constant n_0 , where $n \geq n_0$ such that $f(n) \leq c * g(n)$ for every integer $n \geq n_0$.

$$f(n) \leq c g(n), \quad \text{for } n \geq n_0$$

Then it is pronounced as " $f(n)$ **is** big Oh of $g(n)$ or **$f(n) = O(g(n))$** "

- $f(n)$ describe the actual time of the program
- $g(n)$ is a much simpler function than $f(n)$
- With assumptions and approximations, we can use $g(n)$ to describe the complexity i.e., **$O(g(n))$**

Big-O Notation is a mathematical formula that best describes an algorithm's performance.



3 Big-O Notation

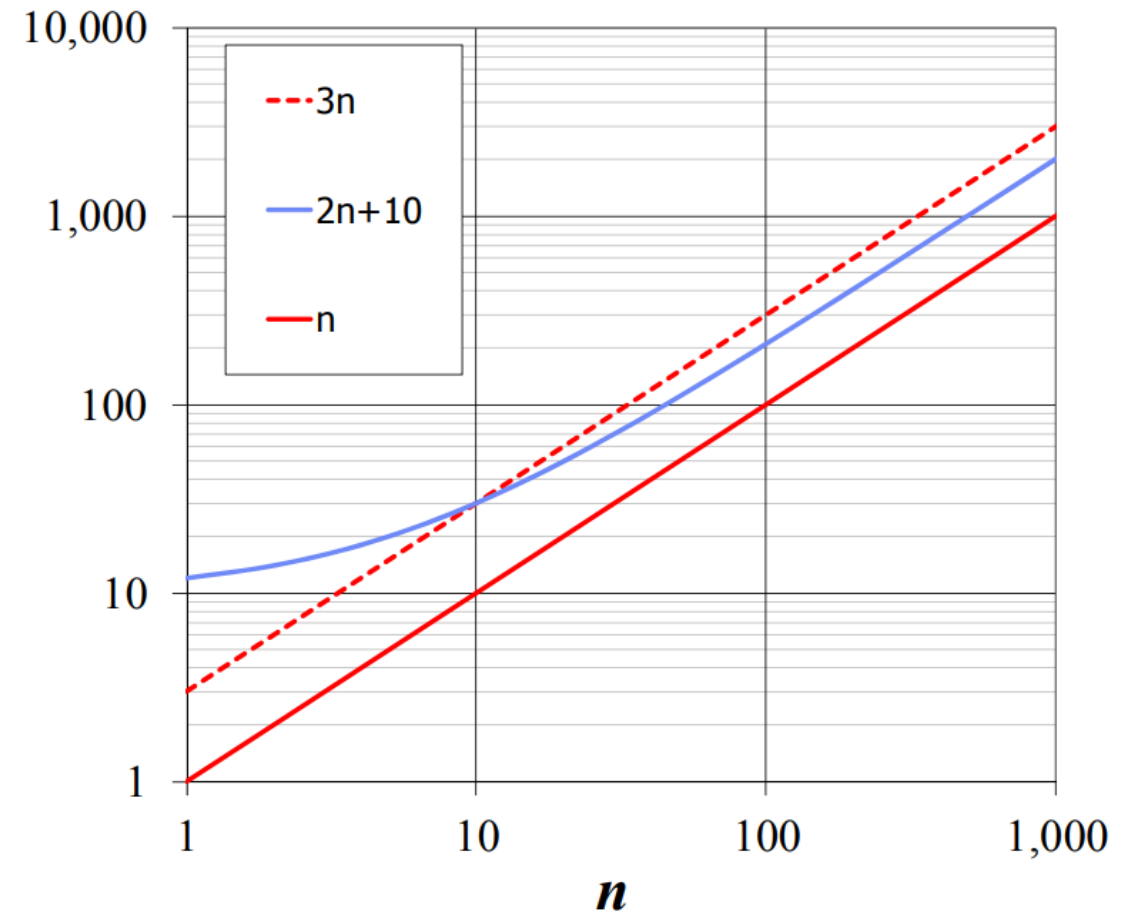
- We use Big-O notation (capital letter O) to specify the order of complexity of an algorithm.
 - *e.g.*, $O(n^2)$, $O(n^3)$, $O(n)$
 - If a problem of size n requires time that is directly proportional to n , the problem is $O(n)$ - that is, order n .
 - If the time requirement is directly proportional to n^2 , the problem is $O(n^2)$, etc.

3 Big-O Examples

- Given functions $f(n)$ and $g(n)$, we say that **$f(n)$ is $O(g(n))$** if there are positive constants, c , and n_0 such that $f(n) \leq c * g(n)$ for every integer $n \geq n_0$.

- Example:
 $T(n) = 2n + 10$
 $T(n)$ is $O(n)$

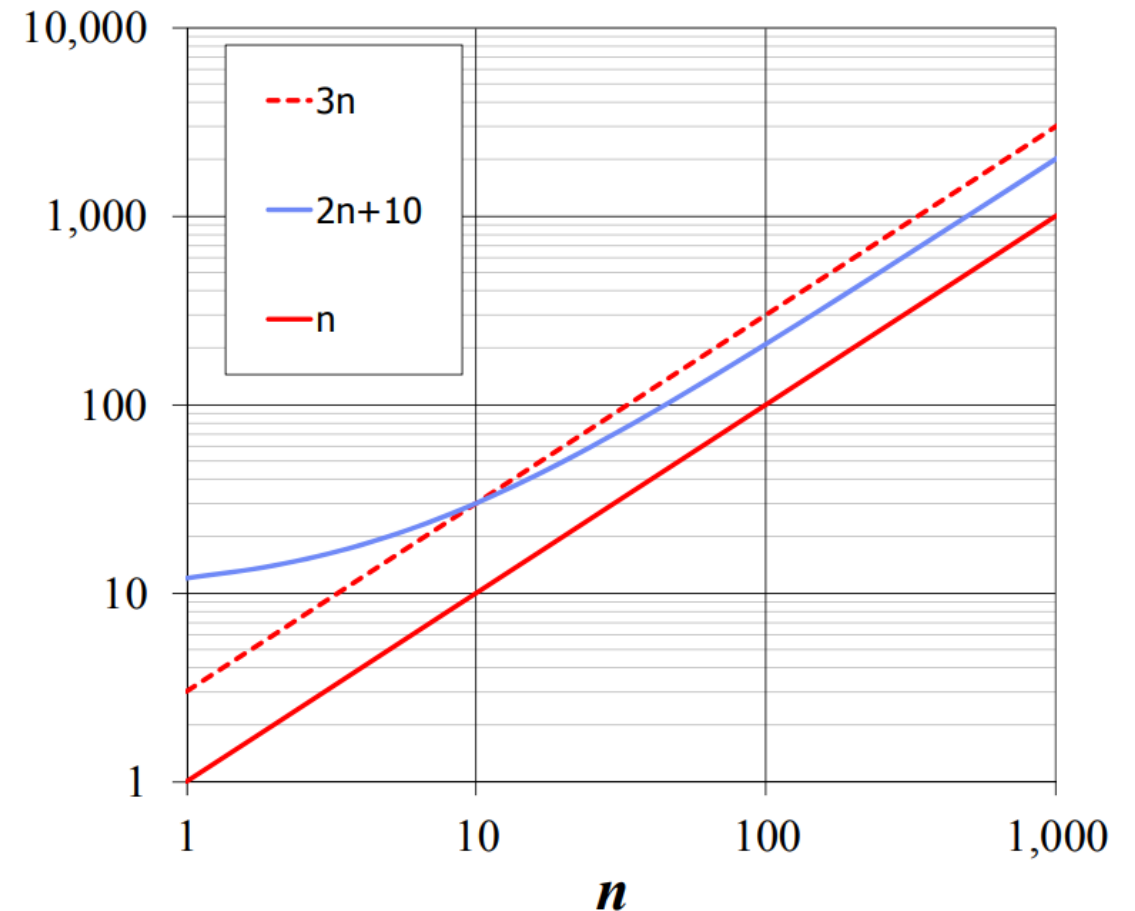
- Question:



3 Big-O Examples

- Given functions $f(n)$ and $g(n)$, we say that **$f(n)$ is $O(g(n))$** if there are positive constants, c , and n_0 such that $f(n) \leq c * g(n)$ for every integer $n \geq n_0$.

- Example:
 $T(n) = 2n + 10$
 $T(n)$ is $O(n)$
- Question:
 - n_0
 - c
 - $g(n)$
 - $f(n) \leq c * g(n)$
 - $f(n)$ is $O(g(n))$**



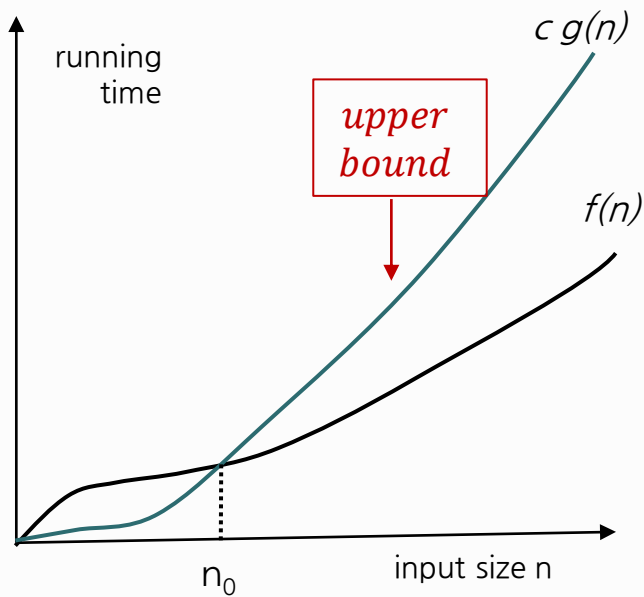
3 Big-O Examples

- Find c and n_0 to justify that the function $7n + 5$ is $O(n)$.

We must find c and n_0 such that

$$7n + 5 \leq c n$$

$$\text{for } n \geq n_0$$



3 Big-O Examples

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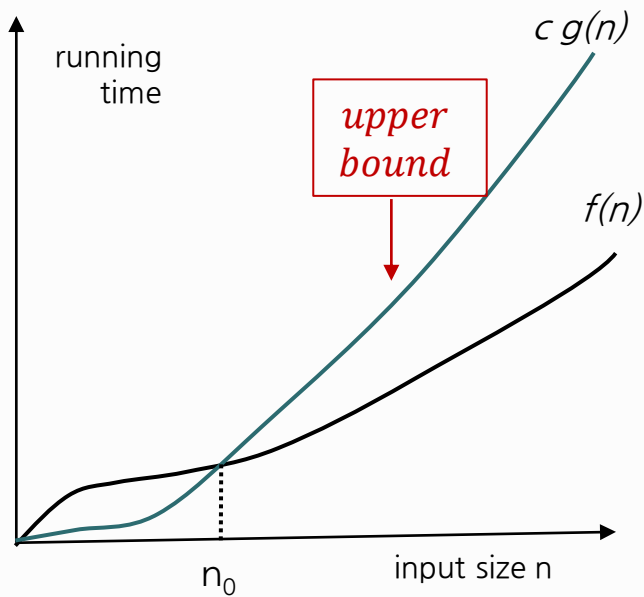
$$\text{for } n \geq n_0$$

$$7n + 5 \leq 7n + n$$

$$7n + 5 \leq 8n$$

$$\text{for } n \geq n_0 = 5$$

Therefore, $7n + 5 \leq c n$ for $c = 8$ and $n_0 = 5$, $g(n) = n$ and $O(n)$



3 Big-O Examples

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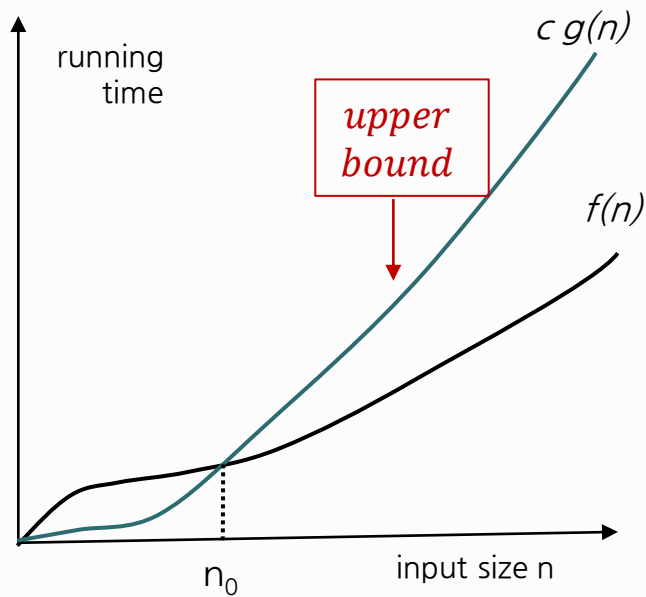
$$\text{for } n \geq n_0$$

$$7n + 5 \leq 7n + n$$

$$7n + 5 \leq 8n$$

$$\text{for } n \geq n_0 = 5$$

Therefore, $7n + 5 \leq c n$ for $c = 8$ and $n_0 = 5$, $f(n)$ is $O(n)$



$$7n + 5 \leq c n \quad \text{for } n \geq n_0$$

$$7n + 5 \leq 12n \quad \text{for } n \geq n_0 = 1$$

Therefore, $7n + 5 \leq c n$ for $c = 12$ and $n_0 = 1$
 $g(n) = n$, $f(n)$ is $O(n)$

3 Big-O Examples

- Find c and n_0 to justify that the function $f(n) = 27n^2 + 16n$ is $O(n^2)$.

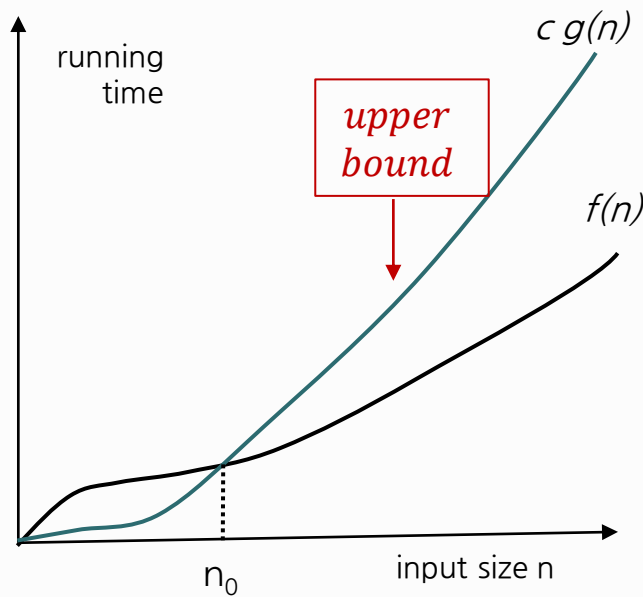
We must find c and n_0 such that

For $16n \leq n^2$

$$27n^2 + 16n \leq 27n^2 + n^2$$

$$27n^2 + 16n \leq 28n^2 \quad \text{for } n \geq n_0 = 16$$

Hence, $c = 28$ and $n_0 = 16$, Therefore, $g(n) = n^2$, $f(n)$ is $O(n^2)$.



$27n^2 + 16n$ is $O(n^2)$, we must find c and n_0 such that

$$27n^2 + 16n \leq 43n^2$$

$$27n^2 + 16n \leq 43n^2 \quad \text{for } n \geq n_0 = 1$$

Hence, $c = 43$ and $n_0 = 1$, Therefore, $g(n) = n^2$, $f(n)$ is $O(n^2)$.

3 Big-O Examples

- Suppose an algorithm requires
 - $T(n) = 7n - 2$ operations to solve a problem of size n

**$7n - 2 \leq 7 * n$ for all $n_0 \geq 1$
i.e., $c = 7, n_0 = 1$**

$O(n)$

**$f(n) \leq c * g(n)$ for
every integer $n \geq n_0$**

- $T(n) = n^2 - 3 * n + 10$ operations to solve a problem of size n

**$n^2 - 3 * n + 10 < 3 * n^2$ for all $n_0 \geq 2$
i.e., $c = 3, n_0 = 2$**

$O(n^2)$

- $T(n) = 3n^3 + 20n^2 + 5$ operations to solve a problem of size n

**$3n^3 + 20n^2 + 5 < 4 * n^3$ for all $n_0 \geq 21$
i.e., $c = 4, n_0 = 21$**

$O(n^3)$

3 Big-O Examples

1) $3n + 2 =$

2) $3n + 3 =$

3) $100n + 6 =$

4) $10n^2 + 4n + 2 =$

5) $6 * 2^n + n^2 =$

6) $3n + 3 =$

7) $10n^2 + 4n + 2 =$

✘ 8) $3n + 2 \neq O(1)$ as $3n + 2$ is **not** $\leq c$ for any c and all $n, n \geq n_0$.

✘ 9) $10n^2 + 4n + 2 \neq O(n)$

Summary

- Big-O Notation is a mathematical formula that best describes an algorithm's performance.
- Big-O notation is often called the asymptotic notation (**점근적 표기법**) since it uses so-called the **asymptotic analysis** (**점근적 분석**) approach.
- Normally **we assume worst-case analysis**, unless told otherwise.
- In some cases, it may need to consider the best, worst and/or average performance of an algorithm

학습 정리

- 1) Big-O(빅 오)은 알고리즘의 수행능력을 잘 나타내는 수학적인 표기법이다
- 2) Big-O를 계산할 때 주어진 함수들에서 가장 근접한 함수를 찾는 것이 좋다

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수고했습니다
곧 다음 시간에
다시 뵙겠습니다

