Introduction and Tools 1

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Introduction

Welcome

Thanks for being here.

Introduce yourself:

- Name
- Year of PhD
- Programming langauge you plan to use
- Answer the question you wish I asked you here

Using and Understanding Your Computer

Intro to Software Engineering

What is “Software Engineering?”

“The systematic application of scientific and technological knowledge, methods, and experience to the design, implementation, testing, and documentation of software.”

What does this mean?

Intro to Software Engineering

What is “Software Engineering?”

“The systematic application of scientific and technological knowledge, methods, and experience to the design, implementation, testing, and documentation of software.”

What does this mean?

Minimize the probability of having a bug and ensure other can understand your code... “Always code as if the guy who ends up maintaining your code will be a violent pyschopath who knows where you live.”

Simple Rules to Live By

These are in no way exhaustive, but are a start

- Don't Repeat Yourself: Writing (c^(1 − gamma) − 1) / (1 − gamma) repeatedly makes it likely you will make a mistake... Also a pain to make sure you change all instances if you use a different utility function.
- Use whitespace wisely.
- Comment and document your code carefully.
- More recommendations

Floating Point Numbers

Computer reads numbers differently than you.

A 16 bit floating point number: $\underbrace{0}_{\text{Sign}}\ \underbrace{01101}_{\text{Exponent}}\ \underbrace{0101010101}_{\text{Mantissa}}$

$$0011010101010101 \rightarrow -1^{\text{Sign}} \left(1 + \sum_{n=1}^{10} \text{Mantissa}_n 2^{-n}\right) 2^{\text{Exponent - Bias}}$$

$$\rightarrow 1(1.3330078125)2^{13-15} = 0.33325$$

Occasionally useful to understand this fact.

Column vs Row Major

Matrices (and higher dimensional) arrays are stored as sequential elements of memory. The order in which they are stored determines whether a language is column or row major.

For example, consider the following matrix: $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$

- A row major language would store this as: 1, 2, 3, 4, 5, 6
- A column major language would store this as: 1, 4, 2, 5, 3, 6

This has performance implications (More info here)

Vectorization

Sometimes useful to recognize that loops can be avoided by using vectorized functions.

Root Finding and Optimization

Bisection: Simplest Root Finding Algorithm

Consider a continuous function $f : \mathbb{R} \to \mathbb{R}$ and $a, b \in \mathbb{R}$ such that $f(a)f(b) < 0$. Then Intermediate Value Theorem states, $\exists c \in (a, b)$ such that $f(c) = 0$.

Require: $f(a)f(b) < 0$
  $fc \leftarrow 10$
  while $|b - a| > tol$ **do**
    $c \leftarrow (a + b)/2$
    $fc \leftarrow f(c)$
    if $fa * fc < 0$ **then**
      $b \leftarrow c$
    else
      $a \leftarrow c$
    end if
  end while

Bisection

Simplest root finding algorithm

- Pros: Relatively fast, simple, guaranteed to find a solution given certain conditions
- Cons: Uses little info about function, not natural to extend to higher than 1 dimension

Newton's Method

Natural follow up to Bisection is Newton's Method

$fk \to f(x_k)$
while $|x_{k+1} - x_k| > tol_x$ **do**
  $x_{k+1} \to x_k - f(x_k)/f'(x_k)$
end while
if $|f(x_k)| < tol_f$ **then**
  Success
else
  Failure
end if

Newton's Method

- Pros: Relatively fast, simple, guaranteed to find a solution given certain conditions
- Cons: Uses little info about function, not natural to extend to higher than 1 dimension

Column vs Row Major: Supplement

Computers have different layers of memory storage. In order to apply operations, data must be moved to a small piece of memory called L1 memory. L1 memory lives directly on the processor and is very fast.

As computers have evolved, they have gotten better at “guessing” what data you will need next. Instead of moving just a single element of an array, the processor will retrieve a small block of consecutive elements.

As you iterate along an array, this means the computer will need to spend less time passing memory between RAM and L1 and can spend more time doing actual operations.

Additional info: online

Back to Column vs Row Major

References

- Numerical Methods in Economics by Kenneth L Judd