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CSCE 240: Advanced Programming Techniques
Lecture 22: Code Optimization

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28TH MARCH 2024

Carolinian Creed: "I will practice personal and academic integrity."

Credits: Some material reused with permission of Dr. Jeremy Lewis. Others used as cited with thanks.

Organization of Lecture 22

- Introduction Section
  - Recap of Lecture 21
  - News / announcements / clarifications
- Main Section
  - Memory optimization
  - Runtime optimization
  - Code maintenance ease
  - Task: Project – PA #5 ongoing – check for issues
- Concluding Section
  - About next lecture – Lecture 23
  - Ask me anything

Introduction Section

Recap of Lecture 21

- We looked at memory management
  - Different types of memories available to a program
  - Summary of vector
  - Care to be taken with deletes
- PA5 due April 4, 2024 (Thursday)

On HW-6 and Quiz 2

- HW-6 will be given on Apr 4 and due on Apr 9; we will consider best-of-4 score
- Quiz 2 will be on Apr 11 (Thursday)

Main Section

Goals of Programming

- Function goals – meets customer's stated functionality needs
  - Meets user's requirements
  - Meets developer's specifications
- Non-functional goals – has desirable characteristics
  - Runs fast
  - Takes less memory
  - Does not abnormally terminate

Code and Developer Objectives

- **Function goals** – meets customer's stated functionality needs
  - Meets user's requirements
  - Meets developer's specifications
- **Non-functional goals** – has desirable characteristics
  - Runs fast
  - Takes less memory
  - Does not abnormally terminate
  - Is well documented
  - …

Example: Sorting numbers

- **Input**: a set of N numbers in any order
- **Output**: a set of N numbers, with a[i-1] <= a[i]

- **Function goals** –
  - Gives correct sorted output
  - Handles all given range of inputs
- **Non-functional goals** – has desirable characteristics
  - Runs fast
  - Takes less memory
    - Linear in size of input
  - Does not abnormally terminate
  - Prints output in formatted manner

Code and Developer Objectives

- Writing any program that meets the functional requirements v/s a good code (i.e., scores high in non-functional requirements)
- But meeting all non-functional goals can be hard
  - Space v/s time trade-off
  - In sorting example:
    - Minimize space:
      - Space: N units for N numbers
      - Time: 1 + 2 + … + (N) operations = (N * (N+1)) / 2 in time operations
    - Minimize time:
      - Space: 2N units
      - Time: N log N
- Furthermore, you want code to be understandable by others
- Printing of output …

Example: Sorting numbers
- **Input**: a set of N numbers in any order
- **Output**: a set of N numbers, with a[i-1] <= a[i]

Concept: Memory Optimization

Why Optimize for Memory?

- Unnecessary drag on performance (slow loading, running of program)
- Program may not run on some platforms
  - Mobile phones, games, embedded devices, setup boxes
- Wastage of (natural) resources – storage media, electricity, …

Reducing Memory Usage

- Use appropriate data type based on range of values possible. Example: int, float, double
- For a group of variables,
  - if size is known,
    - Use data structures (e.g., arrays) of right size
  - Otherwise,
    - dynamic data structures (list) // reduces wastage
      (**alternative**: use arrays with a large size; wastes space)
- Do not have unused variables
- Free space when no longer needed

Example: Sorting numbers
- **Input**: a set of N numbers in any order
- **Output**: a set of N numbers, with a[i-1] <= a[i]

For sorting numbers, use array
For sorting strings, use [?]

Concept: Runtime Optimization

Why Optimize for Time?

- Users expect it !
  - One of the motivations for automation/ programming is speed
- Efficient use of computing resources

Reducing Time – Design of Algorithms

Algo 1:

- current_array = a = Input
- While (true)
  - Check if current_array is sorted (i.e., a[i-1] <= a[i], for i=1 to N).
  - If yes,
    - **Return current_array**
    - current_array = Permute (current_array) (i.e., swap values of any i, j, i not equal j, for i,j =1 to (N-1))

Algo 2:

- current_array = a = Input
- For (i=0; i<(N-1); i++) {
  - For (j=0; j<(N-1); j++) {
    - If(a[i] > a[j])
      - Swap(a[i], a[j])
    - }
  - }
- **Return current_array**

Example: Sorting numbers

- **Input**: a set of N numbers in any order
- **Output**: a set of N numbers, with a[i-1] <= a[i]

Which one will be efficient ?

Reducing Time – Design of Algorithms

Algo 2:

- current_array = a = Input
- For (i=0; i<(N-1); i++) {
  - For (j=0; j<(N-1); j++) {
    - If(a[i] > a[j])
      - Swap(a[i], a[j])
  - }
- }
- **Return current_array**

Algo 3:

- current_array = a = Input
- For (i=0; i<(**N-1**); i++) {
  - For (**j=(i+1)**; j<N; j++) {
    - If(a[i] > a[j])
      - Swap(a[i], a[j])
  - }
- }
- **Return current_array**

Example: Sorting numbers

- **Input**: a set of N numbers in any order
- **Output**: a set of N numbers, with a[i-1] <= a[i]

Which one will be efficient ?

Optimizing for Time – Beyond Algorithms

- Input/ Output takes time
  - Use buffering for reading/ writing large data
  - Do not use print in production code
- Choice of data structure to minimize I/O and processing operations
- Advanced methods
  - Look to do processing in parallel
  - Caching of results // storing (full or partial) results for previous invocations

Concept: Code Management Ease

Software Maintenance Considerations

- Others should be able to understand code and change it
  - Documentation of code
  - Meaningful error messages/ prints/ logging
  - Modularity of code
  - Code reuse / usage of functions

Software Maintenance Considerations

- Others should be able to understand code and change it
  - Documentation of code
  - Meaningful error messages/ prints/ logging
  - Modularity of code
  - Code reuse / usage of functions

-> Increases development time

-> Can slow execution time

-> Can increase memory at runtime, development time

-> Increases / decreases development time

How Much to Document

- Think, how much you need to understand your code after a while
- Some guidelines
  - Main method
  - Function signature and purpose of arguments, return values
  - Key operations inside a function
    - Control structures: loop, conditions
    - Rationale for choice of specific approach taken
  - Side-effects (effects outside the function), if any

Class Exercise – 10 Mins

- **Objective**: Sorting student records

Type	Memory Consideration	Runtime Considerations	Maintenance Considerations
Number (SSNs)			
Strings (Names – F, M, L)			
Grades			
Overall: LastName + Grade			

Discussion: Course Project

Course Project – Knowing About Companies

- **Project**: Develop collaborative assistants (chatbots) that offer useful information about companies
- Specifically, use the EDGAR dataset on companies at: https://www.sec.gov/edgar/searchedgar/companysearch.
  - For Apple, it is: https://www.sec.gov/edgar/browse/?CIK=320193&owner=exclude
- **Each student will choose two companies (from thousand available).**
- Programming assignment programs will: (1) extract data about two companies from 10-k, (2) process it, (3) make content available in a command-line interface, (4) handle any user query and (5) report on interaction statistics.

Core Programs Needed for Project

- Prog 1: extract data from the district **[prog1-extractor]**
- Prog 2: process it (extracted data) based on questions **[prog2processor]**
- Prog 3: make content available in a command-line interface **[prog3-ui]**
- Prog 4: handle any user query **[prog4-userintent2querymapper]**
- Prog 5: report statistics on interaction of a session, across sessions **[prog5-sessionlogger]**

Objective in Programming Assignment # 5:
Record what happens in a chat session and provide summary

- A user may interact with your chatbot for one question or twenty. How did your chatbot do?
- **Record chat your system makes with each user and report on user session as well total usage statistics (since the chatbot was created)**

Approach Suggested

- Under data folder,
  - have a sub-folder called **chat_sessions**
    - When a person starts a chat session (i.e., starts your program and until does not quit), create a file with the " <data>_<time>.txt" as the name. Save the user's utterance and the system's reply there in the order they come. Close this file when the user session ends.
    - Calculate statistics: # user_utterance, #system_utterance and time duration of session
  - have a file called **chat_statistics.csv**.
    - Have a header with columns: S.No, chat_file, # user_utterance, #system_utterance and time taken
    - For each chat file in chat_sessions, there will be a row with the chat statistics you have calculated

Objective in Programming Assignment # 5:
Record what happens in a chat session and provide summary

Approach Suggested

- Under data folder,
  - have a sub-folder called **chat_sessions**
    - When a person starts a chat session (i.e., starts your program and until does not quit), create a file with the " <data>_<time>.txt" as the name. Save the user's utterance and the system's reply there in the order they come. Close this file when the user session ends.
    - Calculate statistics: # user_utterance, #system_utterance and time duration of session
  - have a file called **chat_statistics.csv**.
    - Have a header with columns: S.No, chat_file, # user_utterance, #system_utterance and time taken
    - For each chat file in chat_sessions, there will be a row with the chat statistics you have calculated

- Goal: report statistics on interaction of a session, across sessions [Name: **prog5-sessionlogger**]
- One can invoke it with arguments
  - **prog5-sessionlogger –summary**
    - **There are 12 chats to date with user asking 23 times and system respond 24 times. Total duration is 456 seconds.**
  - **prog5-sessionlogger –showchat-summary 2**
    - **Chat 2 has user asking 2 times and system respond 2 times. Total duration is 4 seconds.**
  - **prog5-sessionlogger –showchat 2**
    - **Chat 2 chat is:**

      …
  - **prog5-sessionlogger –showchat 200**
    - **ERROR: there are only 12 chat sessions. Please choose a valid number.**

Programming Assignment # 5

- Code organization
  - Create a folder in your GitHub called "**prog5-sessionlogger**"
  - Have sub-folders: src (or code), data, doc, test
  - Have data directory as shown in previous slide
    - ./data/**chat_sessions/**
    - ./data/ **chat_statistics.csv**
  - Write a 1-page report in ./doc sub-folder
  - Put a log of system interacting in ./test
  - Send a confirmation that code is done by updating Google sheet; optionally, send email to instructor and TA

- Use concepts learned in class
  - Exceptions
  - File operations
  - Dynamic memory

Class Exercise – 10 Mins

- **Objective**: Course Project

Type	Memory Consideration	Runtime Considerations	Maintenance Considerations	Language specific (C++, Java, Python)
Prog 1: [prog1-extractor]				
Prog 2: [prog2processor]				
Prog 3: [prog3-ui]				
[prog4-userintent2querymapper]				
Prog 5: [prog5-sessionlogger]				

Concluding Section

Lecture 22: Concluding Comments

- We discussed code optimization considerations
  - Memory optimization
  - Runtime optimization
  - Code maintenance ease
  - Language specific

- Looked at examples
  - Sorting
  - Project

About Next Lecture – Lecture 23

Lecture 23: Advanced: Templates

- Templates
- Class Templates
- Function Templates

19	Mar 19 (Tu)	Advanced: Pointers, I/O	
20	Mar 21 (Th)	Advanced: Operator overloading	Prog 4 – end
21	Mar 26 (Tu)	Advanced: Memory Management	Prog 5 – start HW 5 due
22	Mar 28 (Th)	Advanced: Code efficiency	
23	Apr 2 (Tu)	Advanced: Templates	
24	Apr 4 (Th)	AI / ML and Programming	Prog 5 – end
25	Apr 9 (Tu)	Project code summary – student presentation for reuse Review material for Quiz 2	HW 6 due Prog 6 – assembling start
26	Apr 11 (Th)	In class test	Quiz 2 – In class
27	Apr 16 (Tu)	Project presentation	Prog 6 - due
28	Apr 18 (Th)	Project presentation	Last day of class (April 22 per bulletin)
	Apr 23 (Tu)		Reading Day
29	Apr 25 (Tu)	9am – Final Overview	Examination