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CSCE 240: Advanced Programming Techniques
Lecture 18: Advanced Pointers, HW 4 (review), Advanced Testing

PROF. BIPLAV SRIVASTAVA, AI INSTITUTE

14TH 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 18

- Introduction Section
  - Recap of Lecture 17
  - Result of mid-point pulse survey
- Main Section
  - Task: HW 5 – review
  - Review: Pointers and References
  - Concept: Pointer arrays
  - Concept: Function Pointers
  - Concept: Advanced Testing
  - Task: Project – PA #4 ongoing – check on issues
- Concluding Section
  - About next lecture – Lecture 19
  - Ask me anything

Introduction Section

Recap of Lecture 17

- We looked at the c++ standard library
  - Many types of functionality
  - String, I/O, Mathematical libraries most commonly used
- Remember that many implementations of C++ standard library, usually based on different OS or hardware
  - Implements changing specs
- Be ready to implement one's own (rather than reuse), if necessary, for performance
- Testing Background
- Gave HW4, due today
- Gave PA 4, due on Thursday (March 21, 2024)

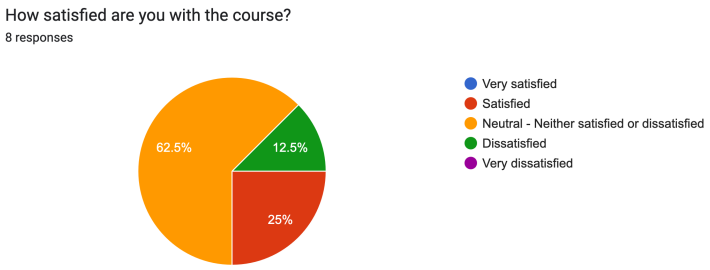
Course Mid-Point Pulse Survey – Results

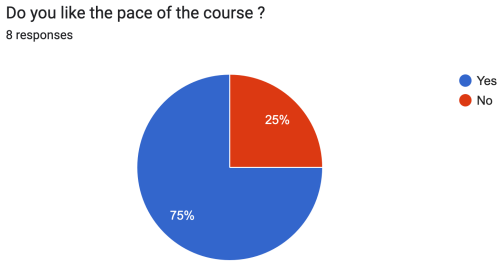
a) Do you like the pace of the course ? - **Y**/N

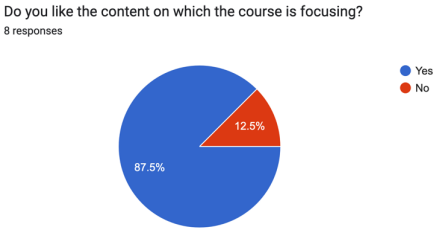
b) Do you like the content on which the course is focusing? - **Y**/N

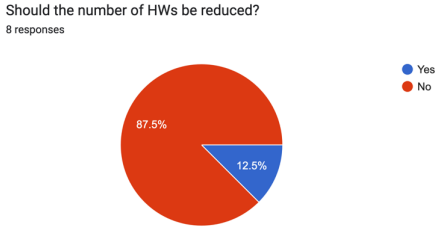
c) Should the number of HWs be reduced? - Y/**N**

d) How satisfied are you with the course?









Course Mid-Point Pulse Survey – Sample Qs

e) What more topic(s) will you like to be covered? - [Open ended]

- More specific c++ knowledge and syntax.
- I want to go over a little bit more about pointers.
- Maybe giving a little more beginner background on code in C++
- A bit more on how to write with C++. A lot of the prerequisites do not teach C++
- N/A, nothing comes to mind, …

f) What would you like, if anything, to be changed in the course? - [Open ended]

- More direct instructions and quicker grading.
- The homeworks are the only things that must use c++ and it feels jarring to discuss the problems from homework and then the project ideas with my peers, I don't know that this can be fixed but it just feels strange.
- I would like to have more clarity on the programming assignment instructions.
- More code context/examples on how certain features work in C++. Sometimes things are challenging to understand having no prior experience with C++
- More homework, less project, so that we can learn C++
- I do think homeworks should be given more time to be worked on.
- I dislike the written exams. A lot of we do and practice is project based, so I wish we were exanimated through project based means.
- More time to complete homeworks or make the homeworks less complicated. It is hard to complete the HWs in 2 days having such short notice. Instead of assigning the HWs on tuesday and making them due thursday, it would be better for them to be assigned thursday and due tuesday or even have a full week to do them.

Upcoming Changes

- More C++ in-class time, background
- Future HWs (2) on Thursdays, to be submitted on Tuesdays
- Advanced topics being considered

Main Section

Home Work 4 (Peer Review)

Due Thursday, March 14, 2024

Home Work (#4) – C++ - Background

- Email programs parse Email headers and show content. The headers have **parts** (e.g., CC, To, From) that are part of a standard and also proprietary extensions.
- Defined with IETF RFC - https://datatracker.ietf.org/doc/html/rfc5322
  - description https://www.tutorialspoint.com/rfc-5322-internet-message-format
  - Examples for Microsoft Outlook and Gmail are shown.
- Let us assume that parts which are common to both are the standard and those unique are proprietary. So, "CC" is common and "X-MS-Has-Attach" is unique.
- Write a program, ***EmailInformationExtractor,*** which, when given a message header from either of the two programs, and a part name, will read the value of the message part.

Microsoft Outlook Header

- Received: from DS7PR19MB5853.namprd19.prod.outlook.com …
- Authentication-Results: dkim=none (message not signed
- Received: from …
- Content-Type: application/ms-tnef; name="winmail.dat"
- Content-Transfer-Encoding: binary
- From: "Sri Naga Sushmitha, Satti" <SATTI@cse.sc.edu>
- To: "Srivastava, Biplav" <BIPLAV.S@sc.edu>
- CC: "Baldwin, Randi" <baldwin@cse.sc.edu>
- Subject: Re: Possible need for … 240
- Thread-Topic: Possible need for printout for .. 240
- Thread-Index: … +AAAIRpoAAAp/ggAAAJH0=
- Date: Tue, 15 Feb 2022 13:52:33 +0000
- Message-ID: <…>
- References: …
- In-Reply-To: <…>
- Accept-Language: en-US
- Content-Language: en-US
- X-MS-Has-Attach:
- X-MS-Exchange-Organization-SCL: -1

Home Work (#4) – C++ - Requirement

- So, program name: ***EmailInformationExtractor***
- Inputs:
  - message header
  - Part name
- Output:
  - Value
- Hint
  - Use regex
  - Use standard libraries

Gmail Header

- Delivered-To: biplav.srivastava@gmail.com
- Received: by 2002:a05:7000:1f97:0:0:0:0 with SMTP …
- X-Google-Smtp-Source: ABdhPJz/…
- Received: from m08b.cvent-planner.com …
- From: Reply-To:To:Message-ID:Subject:MIME-Version:
- Content-Type: List-Unsubscribe; /Tvkdd8/15SWlBA=; …
- Date: Thu, 17 Feb 2022 23:56:12 +0000
- From: AAAI Staff <aaai22@aaai.org>
- Reply-To: <aaai22@aaai.org>
- To: Biplav Srivastava <biplav.srivastava@gmail.com>
- Message-ID: <..>
- Subject: AAAI-22 General Information
- MIME-Version: 1.0
- Content-Type: multipart/alternative; ..
- Content-Type: text/plain; charset=UTF-8
- Content-Transfer-Encoding: quoted-printable

Home Work (#4) – C++ - Code Design

- Create 3 classes:
  - Base class with common parts: BaseEmailHeaderType
  - Children classes with custom parts: GmailHeaderType, OutlookHeaderType
- Use exception to handle likely errors

Peer Review: Homework Assignment #5

1. Go to spread sheet and on ”Homework Assignments - Peer Review” tab. Go for today’s date
2. Go to the row with your name
3. Peer review (10 mins)
    1. Enter serial number of person on your **LEFT** under “ID of code reviewer”
    2. Share code for the reviewer to see
    3. Reviewer: enter review (1-5)
    4. **Note**: negotiate – review code of neighbor or get own’s code reviewed
4. Peer test (10 mins)
    1. Enter serial number of person on your **RIGHT** under “ID of code tester”
    2. Share command line for the tester to see
    3. Tester: enter review (1-5)
    4. **Note**: negotiate – test code of neighbor or get own’s code tested

Peer Reviewing Guideline (10 mins)

- Look out for
  - Can you understand what the code is doing ?
  - Can you explain the code to someone else (non-coder) ?
  - Can you spot possible issues without running it?
    - Are the variables initialized ?
    - Are files closed?
    - Is their unnecessary code bloat ?
- What not to judge
  - Usage of language features, unless they are inappropriate

Assign rating

1: code not available
2: code with major issues
3: code with minor issues
4: -
5: no issues

Peer Testing Guideline (10 mins)

- Look out for
  - Does the program run as the coder wanted it to be (specification) ?
  - Does the program run as the instructor wanted it to be (requirement - customer) ?
  - Does the program terminate abruptly ?
  - Any special feature?
- What not to judge
  - Person writing the code

Assign rating

1: code not available
2: code runs with major issues (abnormal termination, incomplete features)
3: code runs with minor issues
4: -
5: No issues

Discussion on HW

- Peer Code Reviewing
- Peer Testing

Concept: Pointers - Advanced

Recap - Concept: Pointers

- Pointers refer to accessing and manipulating location of variables
  - a = 12 // variable is a, value is 12
  - b = &a // b has the address of a, i.e., 0 here. It is called a pointer
  - c = a // c has the value of a, i.e., 12
  - d = *b // will refer to a. That is, d will be equal to value pointed by b, i.e., 12

Variable	Location	Value
a	0	12
b	4	0
c	8	

Reference: https://www.cplusplus.com/doc/tutorial/pointers/

From 2nd Lecture

Pointer Management

Knowing what a pointer refers to at all times is critical for a (C++) program's stability

- Initialization
- Updates to values, due to
  - Operation
  - Memory allocation
  - Memory de-allocation

Pointers and References in Languages

- C++: fully supported
  - "A pointer is a variable that stores a memory address, for the purpose of acting as an alias to what is stored at that address."
  - Pointer arithmetic
  - Arguments of functions can be passed by value or references
  - **Pointers are first class data types; they can also be passed by value and reference**
- Java, Python: references
  - "A reference is a variable that refers to something else and can be used as an alias for that something else."
  - When a variables is initialized to another variable, references are passed.
  - No pointer arithmetic by programmer

Reference:

- https://nickmccullum.com/python-pointers/#why-dont-pointers-exist-in-python
- https://www.geeksforgeeks.org/is-there-any-concept-of-pointers-in-java/

Pointer v/s References

- One cannot have NULL reference. One must always be able to assume that a reference is connected to a legitimate piece of storage.
- Once a reference is initialized to an object, it cannot be changed to refer to another object. Pointers can be pointed to another object at any time.
- A reference must be initialized when it is created. Pointers can be initialized at any time.

Credit: https://www.tutorialspoint.com/cplusplus/cpp_references.htm

Usage of Pointers

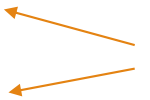
- Can be used to implement passing values to a function by reference
  - In contrast to passing value by copy
  - Memory efficient
- Doing explicit memory management
- Polymorphism

Swapping Values of a Built-in Type

Illustration for integer switching using references

```
void swapNumbersReference(
     int &a, int &b)
{
   int temp = a;
   a = b;
   b = temp;
}
```

Variable	Location	Value
a	0	10
b	4	20
pa	8	0
pb	12	4
ppa	16	8
ppb	20	12



Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 1

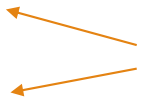
Credit: Fundamentals of Programming C++, Richard L. Halterman, Page 275

Swapping Values of a Built-in Type

Illustration for integer switching using pointers

```
// Demonstrate swapping of numbers
void swapNumbers(int *a, int *b)
{
   int temp = *a;
   *a = *b;
   *b = temp;
}
```

Variable	Location	Value
a	0	10
b	4	20
pa	8	0 (4)
pb	12	4 (0)
ppa	16	8
ppb	20	12



temp

Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 2

Credit: Fundamentals of Programming C++, Richard L. Halterman, Page 275

Pointers and Arrays

- Aggregate memory allocations can be referred by pointers
- Example arrays
  - int anArray[10]; // an array of 10 ints
  - int *apointer; // a pointer to int
  - apointer = anArray;   // will give address of anArray to apointer
- Equivalent statements
  - anArray[5] = 0; *// a [offset of 5] is assigned 0*
    *(apointer+5) = 0; // a pointer + offset of 5 is assigned 0

Credits: https://www.cplusplus.com/doc/tutorial/pointers/

Swapping Values of a Struct

Using references

```
// Demonstrate user defined swap of values using references
void swapPeopleReference(PersonName &a, PersonName &b)
{
   PersonName temp = a;
    a = b;
    b = temp;
}
```

Variable	Location	Value
a	0	{John, First}
b	4	{Jane, Second}
pa	8	0
pb	12	4
ppa	16	8 (12)
ppb	20	12 (8)

Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 3

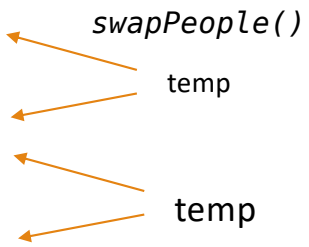
Swapping Values of a Struct

Using pointers

```
// Demonstrate user defined swap of values using pointers
void swapPeople
   (PersonName *a, PersonName *b) {  // Passes pointer by value
           PersonName *temp = a;
           a = b;
           b = temp;}

void swapPeopleCorrect
   (PersonName **a, PersonName **b){
           PersonName *temp = *a;
           *a = *b;
           *b = temp; }
```

Variable	Location	Value
a	0	{John, First}
b	4	{Jane, Second}
pa	8	0
pb	12	4
ppa	16	8 (12)
ppb	20	12 (8)



Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 4

Function Pointers

- Functions can be treated as data
  - Passed using pointers
  - Selected dynamically and iterated

```
int (*f_ptr)(int, int);
f_ptr = &add;
```

Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 5

- Group of functions can be manipulated in an array

```
int (*f[3])(int, int);
f[0] = &add;
f[1] = &multiply;
f[2] = &subtract;
```

Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Argument: 6

Function Pointers

- Functions can be treated as data
  - Passed using pointers
  - Selected dynamically and iterated
- Example
  - **int** (*f_ptr)(**int**, **int**); // declaring a function variable
  - f_ptr = &add; // assigning a value, i.e., function – add here - which matches the function signature
    // i.e., arguments and return type
  - f_ptr(a, b) // invoking the function

Function Arrays

- Group of functions can be manipulated in an array

- Example
  - **int** (*f[3])(**int**, **int**); // Declaring variable

  - f[0] = &add; // Assigning
  - f[1] = &multiply; // Assigning
  - f[2] = &subtract; // Assigning

  - f[i](a, b) // Invoking

Review: Pointers and Examples

- int *a; // a is a pointer to int
- int **a; // a is a pointer to a pointer to a
- int *a[10]; // a is an array of size 10 of pointer to integers
- int (*a)[10]; // a is a pointer to an array of size 10 to integers
- char *(*fp)(int, float *); // fp is a pointer to a function, passing an integer and a pointer to a float,
  // returning a pointer to a char

Code: https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Arguments: 1 through 6

Practical Advice: http://c-faq.com/decl/spiral.anderson.html

Tip for Deciphering Pointer Statements

There are three simple steps to follow:

Starting with the unknown element, move in a spiral/clockwise direction; when encountering the following elements replace them with the corresponding english statements:

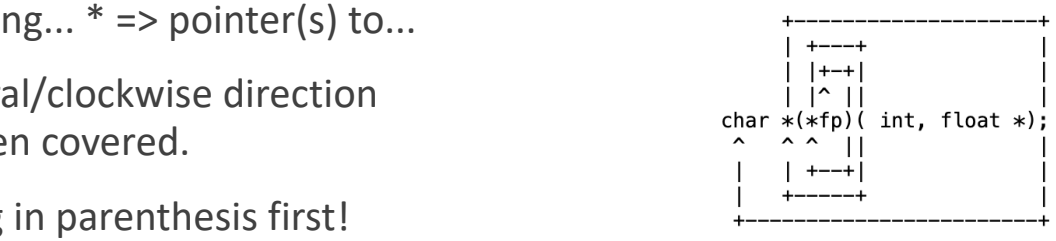
1. [X] or [] => Array X size of... or Array undefined size of... (type1, type2) => function passing type1 and type2 returning... * => pointer(s) to...
2. Keep doing this in a spiral/clockwise direction until all tokens have been covered.
3. Always resolve anything in parenthesis first!

Credit - Practical Advice: http://c-faq.com/decl/spiral.anderson.html

Example #1: Simple declaration

``str is an array 10 of pointers to char''

Example #2: Pointer to Function declaration



``fp is a pointer to a function passing an int and a pointer to float returning a pointer to a char''

Further Exploration

- Tutorials
  - https://www.cplusplus.com/doc/tutorial/pointers/
  - https://www.cprogramming.com/tutorial/function-pointers.html

- Books
  - The Annotated C++ manual, https://www.stroustrup.com/arm.html
  - The C++ Programming Language (4th Edition), Addison-Wesley ISBN 978-0321563842. May 2013, https://www.stroustrup.com/C++.html
  - Fundamentals of C++ Programming , by Richard L. Halterman https://archive.org/details/2018FundamentalsOfCppProgramming/page/n333/mode/2up

Concept: Adv Testing Strategies

Important Types of Testing

- Unit testing
  - Purpose: Check a basic functionality is working. Example, a function or programming assignment in course project
  - Developer does on their own
- Integration testing
  - Purpose: Ensure different components of project work together. Example, complete course project
  - Developer or dedicated tester performs
- Functional testing
  - Purpose: business requirement is met. Checks output, not intermediate results
  - Tester performs
- Acceptance testing
  - Purpose: business requirement is met both functionally and non-functionally like performance, throughput. Checks output, not intermediate results
  - Tester performs; customer performs
- Regression testing
  - Purpose: ensure existing functionality is preserved; especially after a code change
  - Tester performs

We are mostly doing unit and integration testing in the course

Example – Calculating Fibonacci Number

- Concept in mathematics:
  - Fibonacci number of a number is the sum of F numbers of its two predecessors
  - Credit: https://en.wikipedia.org/wiki/Fibonacci_number

  - Popularized by Fibonacci around 1200 AD, known before in India as early as 450 BC

F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	610	987	1597	2584	4181	6765

Implementing and Testing in C++ (V1)

```
int fibonacci(int n)
{
    return fibonacci(n-1) + fibonacci(n-2);
}
```

What can be wrong ?

F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	610	987	1597	2584	4181	6765

Implementing and Testing in C++ (V2)

```
long fibonacci(unsigned int n)
{
   if (n < 2) return n;
   return fibonacci(n-1) + fibonacci(n-2);
}
```

Fixed for handling

- Negative numbers
- Larger return type

But may take too long

Implementing and Testing in C++ (V3) With Measuring Time

```
long fibonacci(unsigned int n)
{
   if (n < 2) return n;
   return fibonacci(n-1) + fibonacci(n-2);
}


int main ()

auto start = std::chrono::steady_clock::now();  // measures start time
long result = fibonacci(n);                     // calls function
cout << "f(" << n << ") = " << result << '\n';  // prints result
auto  end = std::chrono::steady_clock::now(); // measures end time

 // prints time elapsed
```

Fixed for handling

- Negative numbers
- Larger return type

Reports time

* But time includes printing time

Code sample:
https://github.com/biplav-s/course-adv-proglang/blob/main/sample-code/CandC%2B%2B/Class17and18_TestingAdvPointers/src/Class17and18_TestingAdvPointers.cpp

Implementing and Testing in C++ (V4) With Measuring Time

```
long fibonacci(unsigned int n)

{

   if (n < 2) return n;

   return fibonacci(n-1) + fibonacci(n-2);

}



int main ()

auto start = std::chrono::steady_clock::now();  // measures start time
long result = fibonacci(n);                     // calls function
auto  end = std::chrono::steady_clock::now(); // measures end time

cout << "f(" << n << ") = " << result << '\n';        // prints result


 // prints time elapsed
```

Fixed for handling

- Negative numbers
- Larger return type

Reports time

Testing Frameworks

- Java
  - JUnit
    - Code sample: https://github.com/biplav-s/course-adv-proglang-s23/tree/main/sample-code/Java/L17_Testing/src/autotest
- C++
  - Boost.Test
  - Google Test

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 session

Objective in Programming Assignment # 4:
Remove Requirement on User to Know Supported Queries!

- Until now, use needed to know what the program supports.
- **Can the system adapt rather than ask the user to adapt ?**
- **Approach Suggested**
  - Take user's utterance
  - Understand query and company of interest
  - Match to the closest supported query
    - ***Intents***: [Parts and Items] **+ 3 more**
    - Also, add a confidence estimate
  - If confidence greater than a threshold and if the company is supported
    - Run the query,
  - Otherwise
    - Ask user to re-phrase and ask again

- Program should do the following:
  - Run in an infinite loop until the user wants to quit
  - Handle any user response
    - **[#1]** User can quit by typing "Quit" or "quit" or just "q"
    - User can enter any other text and the program has to handle it. The program should write back what the user entered and say – "I do not know this information".
  - Handle known user query
    - "Tell me about ***IBM***" or "What are the risk factor for ***IBM***?" => (Part 1), or (Part 1: Item 2), accordingly
    - "What markets does ***IBM*** operate in?", "Are there aby disclosures from ***IBM***?" => (Part 2)
    - "who are the directors? " => (Part 3: Item ..) // assume company, or tell of all companies, or ask …
    - "Tell me about ***IBM's*** statements" => (Part 4)
    - …
    - "**Tell me everything**" => ***Give all information extracted***

Intents: [Parts and intents] +
tell everything, chitchat and quit

Content Reference: Queries for (Answers) Data We Have

- What does the (company) do? // Answers in Part 1
  - What is the (company's) business?
  - What are (company's) risk factors?
  - What does (company) own?
  - …
- Where does (company) operate? // Answers in Part 2
  - What has (company) disclosed?
- How is (company) structured? // Answers in Part 3
  - Who is (company's) CEO?
  - How much does (person) earn?
  - …
- What was in (company) statements? // Answers in Part 4
  - …

Concepts: 10-K, Parts, Items

Parts

- Part 1: Business Background and Risks
  - Item 1: Business
  - Item 2: Risk factors
  - Item 3: Properties
  - Item 4: Legal Proceedings
- Part 2: Operations and Disclosures
  - .. Market
  - .. Disclosures
- Part 3: Company Structure
  - Directors
  - Compensation
- Part 4: Financial Statements
  - Statements

Hint: Programming Assignment # 4

- Goal: **make an utterance to intent query mapper** [Name: **prog4-userintent2querymapper**]

- Program **may** do the following – pseudo-code
  - Run in an infinite loop until the user wants to quit
  - Get a user utterance. We will call it u
  - See if u matches to supported intents in Q **// 3 + financial doc info type**
    - Split u into words
    - For each information type – supported query q - in Q
      - Split q into words - w
      - Check how many words of u and w match **// one can also consider partial match**
      - Compute a percentage of match
    - q_i: let this be the query with the highest match percentage
    - If q_i > 0.7 **// 0.7: parameter**
      - Consider it to be the query. Inform user and execute; give information (result)
    - Else
      - Tell user cannot understand u. Example: rephrase and try again.

Programming Assignment # 4

- Code organization
  - Create a folder in your GitHub called "**prog4-userintent2querymapper**"
  - Have sub-folders: src (or code), data, doc, test
  - 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

- Use concepts learned in class
  - Classes
  - Exceptions
  - UML Diagrams

Review of Assignments PA1,PA2, PA3 - Feedback

- Do not put *.class, a.out or .exe in git; it is a binary
- Put a Readme.md or Readme.txt in your assignment's main directory so that the reviewer knows what is the main file, where is the data, how is your program invoked, etc
- Avoid hardcoding in code
  - Paths an absolute no-no
  - Data based string extraction
    - [Students have hardcoded line number, character offset, or simply written values in code (manual extraction). Regex hardcoding most common.]
    - Will make code hard to generalize; no one else will be able to reuse
    - Regex makes extraction easy to understand and simpler
    - Loading extraction logic (regex, string indexes) from a config file makes code easy to generalize

Suggestion: Externalizing Extraction Logic From Code

Loading extraction logic (regex, string indexes) from a config file makes code easy to generalize

Configuration file (Data)

```
# Format: entity name, regex pattern
# Format: entity name, line, start index, end index
IBM, (I|i)bm
```

Code

1. Read configuration file
2. Read data stream
3. For each pattern
   extract entity value from data stream
4. Close files
5. *# Do rest of the processing*

Now, to extract a new pattern or change extraction rule, we just have to modify the configuration file!

Concluding Section

Lecture 18: Concluding Comments

- We looked pointers and references
- Pointers are useful for dynamic behavior - memory management, function invocation, …
- Reviewed HW4
- Checked on PA4, due on Thursday (March 21, 2024)

About Next Lecture – Lecture 19

Lecture 19: Advanced Input / Output

- Pointers (remaining topics)
- Adv I/O
  - Buffering
  - Seek/ going to specific data items

12	Feb 15 (Th)	OO – Constructor, Destructor	Prog 2 – end
13	Feb 20 (Tu)	Review: inheritance, Polymorphism	Prog 3 - start
14	Feb 22 (Th)	In class test	Quiz 1 – In class
15	Feb 27 (Tu)	In class Project Review: PA1 and PA2	
16	Feb 29 (Th)	OO – operators, access control	Prog 3 - end Semester - Midpoint
	Mar 5 (Tu)		Spring break – No class
	Mar 7 (Th)		Spring break – No class
17	Mar 12 (Tu)	C++ standard library, Testing strategies	Prog 4 - start
18	Mar 14 (Th)	Advanced: Pointers	HW 4 due
19	Mar 19 (Tu)	Advanced: Pointers, I/O	
20	Mar 21 (Th)	Advanced: Operator overloading	Prog 4 – end (March 26, 2023)