Lab 3 Group BEERZ

Programmer's Guide

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**Introduction**

***~~This document contains the summary of the implementation of the “Wi-11 Machine” linking loader, and will cover all of the components that are used in the execution of the linking loader. The linking loader will accept one or more object files that have been assembled, properly combine the object files and produce a single object file that is capable of being run on the “Wi-11 Machine” simulator. Object files are to follow the format laid out in the Assembler User’s Guide; this document is written cased on the assumption that the reader is familiar with this format. Throughout the guide, names of classes and system defined types will be in Bold Courier Font. Classes and methods are public unless stated otherwise.~~***

**Linking Loader Overview**

***~~The linking loader is capable of handling multiple object files, and linking them together in order to produce a single executable file that can be input to the simulator. The linking loader is able to handle linking multiple relocatable programs, one relocatable program with no external symbols, and one absolute program with no external symbols. When the linking loader runs, the entry point is the class entitled Main, which is implemented in the Loader package in the Main.java file. Main is responsible for accepting and handling command line arguments and producing the simulator-executable object file.~~***

**Directory Structure**

**The loader's files are in a parent directory named “cse-560-beerz,” that contains two subfolders named Loader and Common (the Common subfolder contains classes that are used in all three components of the Wi-11 machine). The following files are in the Loader directory:**

1. **Main.java**
2. **Contains the implementation of the Main class, which handles all disk and console I/O and oversees the linking process.**
3. **Loader.java**
4. **Contains the implementation of the stateless Loader class, which parses object files into instances of the ObjectFile class.**
5. **ObjectFile.java**
6. **Implements the ObjectFile class, which represents an object file loaded in memory. This class stores an object file's segment name, execution start address, text records, imported and exported symbols, and relocation information.**

**The following files are in the Common directory:**

1. **ByteOperations.java**
2. **Implements the static ByteOperations utility class, which provides functions for modifying binary data.**
3. **Error.java**
4. **The Error class is used by the Assembler, Loader, and Simulator to keep track of errors encountered while assembling, loading, or simulating a program.**
5. **MemoryBank.java**
6. **A MemoryBank represents an array of 16-bit memory. It provides functions for reading and writing memory, as well as resolving symbol values and relocating binary data.**
7. **SymbolEntry.java**
8. **A SymbolEntry represents a location in memory that must be modified by the Loader. The SymbolEntry may be associated with a Symbol, in which case the Symbol's value must be inserted at the memory location. Otherwise, the SymbolEntry just indicates that the value in memory must be modified if it is relocated.**
9. **Symbol.java**
10. **A Symbol is a name/value pair with an extra flag that defines whether the Symbol is relocatable or constant.**
11. **SymbolTable.java**
12. **A SymbolTable is an internal representation mapping names to Symbols.**

**The Loader folder contains the subfolder “/tests” that contains the test assembly and object files that were used in the testing of the Loader.**

**The Loader folder also contains the subfolder “/docs” that contains the User’s Guide, Programmer’s Guide and the Testing Plan. Contained within the “/docs” directory is another subfolder “/Meeting Minutes” that contains the minutes for each design meeting that took place.**

**Design Conventions**

**Across the files in our implementation, several design conventions were followed. These include the capitalization of class names and package names, like Main or Loader, lower-case names for variables, and mixed-case names for method titles like “getSegmentName”. Also, care was taken to limit the length of lines to less than 90 characters. On a whole, our lab was designed to be object-oriented. The objects that are used to represent the symbols and object files follow the object-oriented convention of encapsulation and data hiding.**

**Module Inter-Relationships**

**The core linking loader algorithm is implemented in the Main and Loader classes. These modules use the ObjectFile, SymbolTable, Symbol, SymbolEntry, and MemoryBank classes to represent the state of the object files. In addition, the Error class is used for error reporting, and the ByteOperations utility class is used for binary modification functions.**

**Data Structures**

**There are several important data structures that are used by the loader in the creation of the output executable. The following is a listing of the data structure, the file it appears in, the usage of the data structure, its implementation, and its invariant.**

1. **Object: “ObjectFile” defined by ObjectFile.java**
2. **Represents a complete “Wi-11 Machine” object file, including the segment name, execution start address, text records, imported and exported symbols, and relocation information.**
3. **Implemented as a String for the segment name, an int for the start address, a MemoryBank for the text records, two Lists of SymbolEntrys for the imported and exported symbols and the relocation information.**
4. **Invariant: length of the segment name must be 6 and the start address must be in the range [x0, xffff]. The MemoryBank must not be null.**
5. **Object: “MemoryBank” defined by MemoryBank.java**
6. **Represents an array of 16-bit memory.**
7. **Implemented as a HashMap<Integer, Short> and two ints to track the first and last address containing data.**
8. **Invariant: the first and last addresses tracked by the MemoryBank must correspond to the smallest and largest int keys (respectively) in the HashMap<Integer, Short>.**
9. **Object: “SymbolEntry” defined by SymbolEntry.java**
10. **Represents a location in memory that must be modified by the Loader.**
11. **Implemented as a String that may be null for relocation records, or may contain the name of a Symbol associated with the entry, and three ints which represent a memory address and the indices of the most significant and least significant bits that need modified.**
12. **Invariant: the address must be in the range [x0, xffff], the index of the most significant bit must be larger than that of the least significant bit. Both bit indices must be in the range [0, 16].**
13. **Object: “Error” defined by Error.java**
14. **Represents a loader error with a message and an optional object file line number.**
15. **Implemented as a String to store the message, an int to store the line number, and a boolean to indicate whether the error makes use of the line number.**
16. **Invariant: the message must not be null, and the line number must be greater than zero.**
17. **Object: “Symbol” defined by Symbol.java**
18. **Represents the name/value pair of a defined symbol.**
19. **Implemented as a String for the symbol name, an int to store its value, and three booleans indicating whether the symbol is relocatable, imported, or exported.**
20. **Object: “SymbolTable” defined by SymbolTable.java**
21. **Represents the internal mappings of names to Symbols.**
22. **Implemented as a HashMap<String, Symbol>.**
23. **Invariant: Only unique Symbols can be entered into the SymbolTable.**

**Component Descriptions**

**This section provides a detailed description of both the client- and implementation-side view of every component used in the program.**

**Client-Side**

1. **Main**
2. **Description: The Main component is the entry point into the loader program. It accepts the command line arguments from the user, such as the input files, output filename, and an option to generate a listing.**
3. **Loader**
4. **Description: The Loader component parses object files into in-memory ObjectFile reperesentations, which can then be relocated and linked.**
5. **Mathematical Model:**

**The Loader has no state.**

1. **Constraint:**
2. **ObjectFile**
3. **Description: The ObjectFile component holds the in-memory representation of an object file. The ObjectFile can then be relocated and linked into an executable file.**
4. **Mathematical Model:**

**ObjectFile = Start Address + Segment Name + MemoryBank + Symbol Entries + Relocation Records + Relocatable**

**Implementer-Side**

**Main**

1. **Description: The Main class contains the main method which is the entry point into the loader program.**
2. **State: None**
3. **Algorithm:**

**Parse input filenames from arguments**

**Parse output filename from arguments and attempt to open an output stream**

**Determine whether to generate a listing from the arguments**

**Parse the load address from arguments, if one is given**

**Read all input file data into Strings**

**Parse each input file into an ObjectFile and relocate appropriately**

**Resolve symbol values in each ObjectFile and combine them into one MemoryBank**

**Write header record, text records, and end record**

**Close output stream**

1. **Main Methods**
2. **Method Name: main**
3. **Description: Program entry point**
4. **Parameters: args[]**
5. **Requires: 1 or more input files and an output filename**
6. **Alters: outfile**
7. **Returns: void**
8. **Throws: None**
9. **Method Name: printUsageInformation**
10. **Description: Prints usage information to the console. Shows:**

**Usage: java Loader.Main [inputfiles] -o outfile [options]**

**-l Generating listing**

**-a addr Relocate program to addr (4-digit hex memory address)**

**Note: if linking an absolute object file, it must come first in the file list.**

1. **Parameters: None**
2. **Alters: System.out**
3. **Ensures: System.out = #System.out + [usage info]**
4. **Returns: void**
5. **Method Name: readAllText**
6. **Description: Reads all text in the file at the given path location into a string.**
7. **Parameters: String filename - Path to desired file**
8. **Requires: valid file**
9. **Returns: A string containing all the data existing in the desired file.**
10. **Throws: IOException**
11. **Method Name: writeAllText**
12. **Description: Writes all the given text to the file existing at the path location**
13. **Parameters: String filename - Desired output file name, String data – data to be written to file**
14. **Alters: The specified file on the file system**
15. **Ensures: The specified file is overwritten or created if it does not exist on the file system**
16. **Returns: void**
17. **Throws: IOException**

**Loader**

1. **Description: The Loader parses an object file into an ObjectFile representation.**
2. **State: none**
3. **Alogrithm:**

**for each line in object file:**

**if line is a header record:**

**Extract the segment name, load address, and segment size**

**else if line is a text record:**

**Extract address and value and write them to the output MemoryBank.**

**if line has a modification record suffix:**

**Create and save a SymbolEntry for the address.**

**else if line is an export record:**

**Extract the symbol name and value**

**Define a new Symbol in the output SymbolTable**

**else if line is an import record:**

**Extract the symbol name, address, and bit mask**

**Create a new SymbolEntry with the name, address, and bit mask**

**else if line is an end record:**

**Extract the execution start address**

**end for**

**Create and return a new ObjectFile with the parsed segment name, load address, MemoryBank, SymbolTable, and lists of SymbolEntrys.**

1. **Loader Methods**
2. **Method Name: load**
3. **Description: Takes object file data as a parameter and returns an ObjectFile that represents that data.**
4. **Parameters: String data**
5. **Requires: A valid “Wi-11 Machine” object file**
6. **Ensures: the output ObjectFile is a valid in-memory representation of the input data**
7. **Returns: ObjectFile**
8. **Throws: Exception**
9. **Method Name: validateSymbolName**
10. **Description: This method accepts a symbol name and determines whether the name is valid.**
11. **Parameters: String name**
12. **Ensures: If the symbol name is valid, the output String will be null. If it is invalid, the output String will contain an error message for display to the user.**
13. **Returns: String**

**ByteOperations**

1. **Description: A utility class that provides functions to extract and modify binary data.**
2. **ByteOperations Methods:**
3. **Method: parseHex**
4. **Description: This method converts a hex number represented in a String to an integer value.**
5. **Parameters: String hex**
6. **Ensures: hex is a valid hexadecimal number representation.**
7. **Returns: an integer value representing the input hex value.**
8. **Throws: Exception**
9. **Method: extractValue**
10. **Description: This method extracts bit values from a given integer.**
11. **Parameters: int value, int start, int end**
12. **Requires: start < end**
13. **Returns: an integer value representing the extracted bits.**
14. **Method: getHex**
15. **Description: This method gets a string representation of a given integer value.**
16. **Parameters: int value, int numCharacters**
17. **Ensures: All but the least significant hex digits specified by numCharacters are removed.**
18. **Returns: a string representation of the integer value in hexadecimal form.**
19. **Method: getBit**
20. **Description: This method returns true if the bit in “value” at the specified right-aligned index is 1.**
21. **Parameters: int value, int index**
22. **Returns: A boolean value indicating if the specified bit is 1.**
23. **Method: extendSign**
24. **Description: Extends the sign bit from the given most significant bit.**
25. **Parameters: int value, int mostSignificantBit**
26. **Returns: the sign-extended version of the given input value**
27. **Requires: 0 < mostSignificantBit < 32**
28. Ensures: if the bit indexed by mostSignificantBit is set, all the bits to the left of that bit will also be set.
29. **Throws: Exception**

**ObjectFile**

1. **Description: Each instance of this class represents an object file loaded in memory. This class stores an object file's segment name, execution start address, text records, imported and exported symbols, and relocation information.**
2. **State:**
3. **private List<SymbolEntry> symbolEntries**
4. **private List<SymbolEntry> relocationRecords**
5. **private MemoryBank memory**
6. **private SymbolTable symbols**
7. **private boolean relocatable**
8. **private int startAddress**
9. **private String name**
10. **ObjectFile Methods**
11. **Method: getSymbolEntries**
12. **Description: Gets the List of SymbolEntries representing imported Symbols.**
13. **Returns: List<SymbolEntry>**
14. **Method: getRelocationRecords**
15. **Description: Gets the List of SymbolEntrys representing relocation records.**
16. **Returns: List<SymbolEntry>**
17. **Method: getMemoryBank**
18. **Description: Gets the MemoryBank representing the text records of this ObjectFile.**
19. **Returns: MemoryBank**
20. **Method Name: getSymbols**
21. **Description: Gets the SymbolTable representing the Symbols defined in this ObjectFile.**
22. **Returns: SymbolTable**
23. **Method Name: isRelocatable**
24. **Description: Returns true iff this ObjectFile is relocatable.**
25. **Returns: true iff this ObjectFile is relocatable.**
26. **Method Name: getStartAddress**
27. **Description: Returns the address to start execution at in this ObjectFile.**
28. **Returns: int**
29. **Method Name: getSegmentName**
30. **Description: Returns the segment name specified in this ObjectFile.**
31. **Returns: String**
32. **Method Name: relocate**
33. **Description: Relocates this ObjectFile's SymbolTable, MemoryBank, and start address.**
34. **Parameters: int a, int b**
35. **Returns: void**

**Error**

1. **Description: An instance of Error describes an error encountered in the assembly of the input program.**
2. **State: private int line, private String message, private boolean hasLine**
3. **Error Methods:**
4. **Method Name: hasLineNumber**
5. **Description: Used to determine whether this is associated with a line number.**
6. **Returns: true if and only if this error has a line number associated with it**
7. **Method Name: getLineNumber**
8. **Description: Gets the line number associated with this Error.**
9. **Returns: 0 if this.hasLine = false; otherwise returns the line number of this Error**
10. **Method Name: getMessage**
11. **Description: Gets the message describing this Error to the user.**
12. **Returns: the message associated with this Error**

**SymbolEntry**

1. **Description: A SymbolEntry consists of a symbol, an address, and a bit mask.**
2. **State:**
3. **private String symbol**
4. **private int address**
5. **private int leastSignificantBit**
6. **private int mostSignificantBit**
7. **SymbolEntry Methods**
8. **Method Name: getAddress**
9. **Description: Gets the address of this SymbolEntry.**
10. **Returns: int**
11. **Method Name: getSymbol**
12. **Description: Gets the name of the Symbol associated with this SymbolEntry.**
13. **Returns: String**
14. **Method Name: setAddress**
15. **Description: Sets the address of this SymbolEntry.**
16. **Parameters: int a**
17. **Returns: void**
18. **Method Name: getLeastSignificantBit**
19. **Description: Gets the least significant bit to insert the Symbol into.**
20. **Returns: int**
21. **Method Name: getMostSignificantBit**
22. **Description: Gets the most significant bit to insert the Symbol into.**
23. **Returns: int**
24. **Method Name: getMask**
25. **Description: Gets the bitmask for this SymbolEntry.**
26. **Returns: short**
27. **Method Name: getInverseMask**
28. **Description: Gets the inverted bitmask for this SymbolEntry.**
29. **Returns: short**

**MemoryBank**

1. **Description: A MemoryBank represents an array of 16-bit memory. It provides functions for reading and writing memory, as well as resolving symbol values and relocating binary data.**
2. **State:**
3. **private Map<Integer, Short> data**
4. **The concrete representation of the memory. This dictionary maps 16-bit unsigned addresses to 16-bit signed values.**
5. **private int firstAddress**
6. **The first address with data in this MemoryBank.**
7. **private int lastAddress**
8. **The last address with data in this MemoryBank.**
9. **private int startAddress**
10. **The address (relative to the origin) at which to start execution.**
11. **Program Methods:**
12. **Method: write**
13. **Description: Sets the memory cell at the given address to the given value.**
14. **Parameters: int address, short value**
15. **Alters: this.data**
16. **Requires: 0 <= address < 65,536 and −*32,768* < value < *32,767***
17. ***Alters: this.data***
18. Ensures: this.data = #this.data + (address, value)
19. **Returns: void**
20. **Method: read**
21. **Description: Gets the value of the memory cell at the given address.**
22. **Paramaters: int address**
23. **Requires: 0 <= address < 65,536**
24. **Returns: short**
25. **Method: displayPage**
26. **Description: Prints the state of the given memory page (bit-shifted all the way to the right) to the given output stream.**
27. **Parameters: PrintStream output, int page**
28. **Requires: output is open**
29. **Alters: output**
30. **Ensures: output = #output + [page of memory from this.data]**
31. **Returns: void**
32. **Method: relocate**
33. **Description: Relocate the data in this MemoryBank from the given starting location to the given new location, using the given relocation records.**
34. **Parameters: int a, int b, List<SymbolEntry> relocationRecords**
35. **Returns: void**
36. **Method: resolveSymbols**
37. **Description: Insert values from the given SymbolTables into the memory locations specified by the given List of SymbolEntrys.**
38. **Parameters: List<SymbolTable> symbols, List<SymbolEntry> symbolEntries**
39. **Returns: void**
40. **Throws: Exception**
41. **Method: insertInto**
42. **Description: Insert the data from this MemoryBank into the given MemoryBank, overwriting any overlapping data.**
43. **Parameters: MemoryBank bank**
44. **Returns: void**
45. **Method: getRecords**
46. **Description: Gets a String of text records representing this MemoryBank.**
47. **Returns: String**

**Symbol**

1. **Description: A Symbol is a name-value pairing that has a flag for whether or not the symbol is relocatable or absolute. It also has flags indicating whether the Symbol is imported, exported, or neither.**
2. **State: private String name, private int value, private boolean isRelocatable, private boolean \_isImport, private boolean \_isExport**
3. **Symbol Methods:**
4. **Method: getName**
5. **Description: Returns the name of this Symbol**
6. **Returns: String**
7. **Method: getValue**
8. **Description: Gets the value of this Symbol**
9. **Returns: int**
10. **Method: isRelocatable**
11. **Description: Returns true if this Symbol is relocatable, false if not.**
12. **Returns: boolean**
13. **Method: isImport**
14. Description: returns true iff the import flag is set for this **Symbol**, indicating that this **Symbol** must be defined in another linked object file.
15. **Returns: boolean**
16. **Method: isExport**
17. **Description: returns true iff the export flag is set for this Symbol, indicating that this Symbol will be exported to other linked object files.**
18. **Returns: boolean**
19. **Method: setExport**
20. **Description: Sets the export flag for this Symbol.**
21. **Returns: void**

**SymbolTable**

1. **Description: An instance of this class maintains a mapping between Symbols and their values.**
2. **State: private Map<String, Symbol>**
3. **SymbolTable Methods:**
4. **Method: define**
5. **Description: Adds a given Symbol to this SymbolTable.**
6. **Parameters: Symbol symbol**
7. **Alters: this**
8. **Ensures: this = #this + symbol**
9. **Method: define**
10. **Description: Defines an alias for another Symbol.**
11. **Parameters: String alias, String target**
12. **Alters: this**
13. **Ensures: this = #this + alias**
14. **Method: hasSymbol**
15. **Description: Returns true if this table contains a Symbol that matches the given name.**
16. **Parameters: String name**
17. **Returns: boolean true if and only if name matches a Symbol in this**
18. **Method: get**
19. **Description: Gets the Symbol mapped to the given name, or null if none exists in this.**
20. **Parameters: String name**
21. **Returns: Symbol corresponding to name input**
22. **Method: size**
23. **Description: Gets the number of defined Symbols in this table.**
24. **Returns: int number of defined Symbols**
25. **Method: getSymbols**
26. **Description: Gets the set of all address/value pairs in this table.**
27. **Returns: Collection<Symbol>**
28. **Method: relocate**
29. **Description: Relocate all relocatable symbols from a to b.**
30. **Parameters: int a, int b**
31. **Returns: void**