A First Course in Computer Programming
Laboratory Manual
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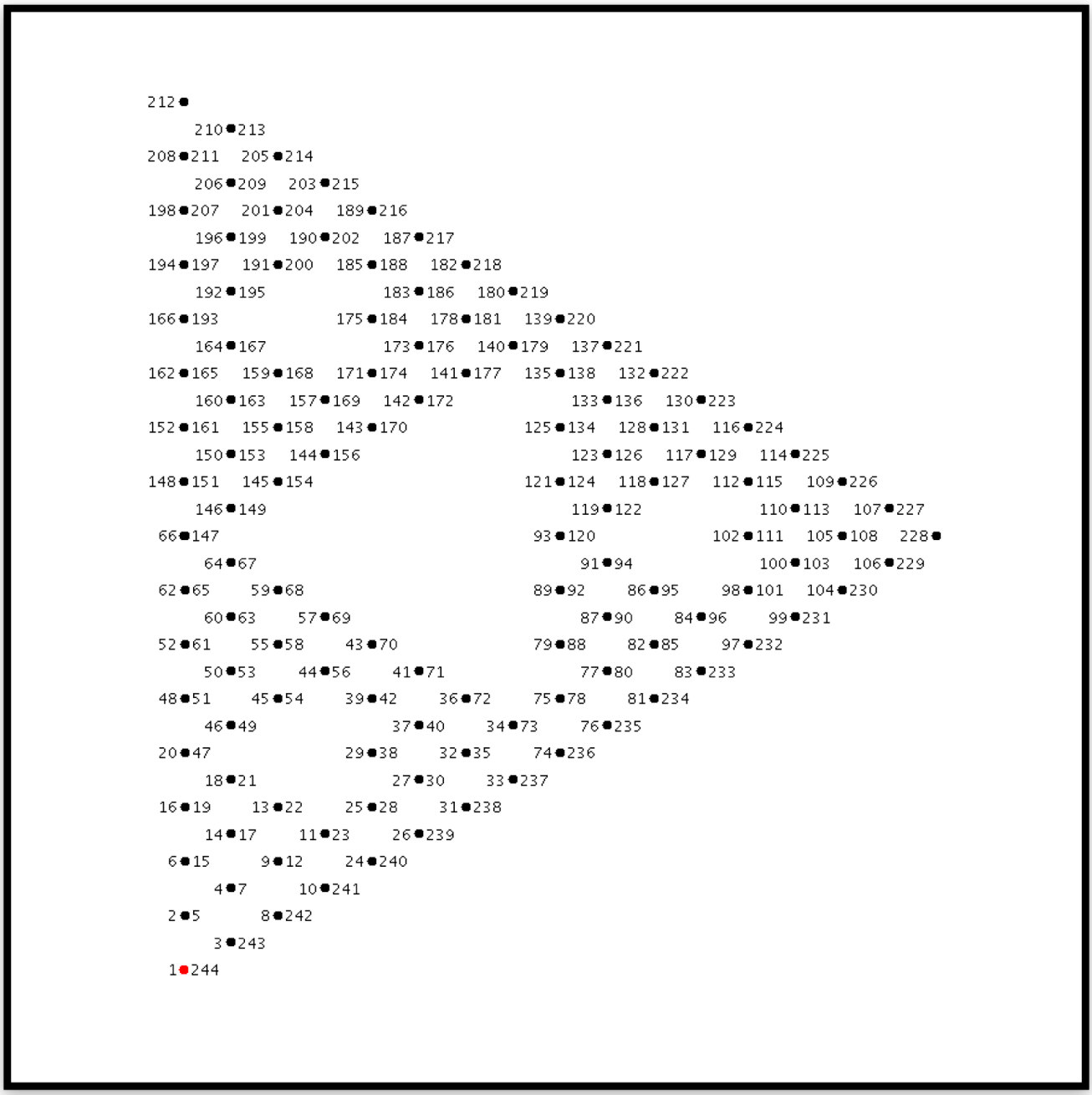


Contents

1 Entrance

Marcel Proust on WISDOM

We do not receive wisdom, we must discover it for ourselves, after a journey through the wilderness which no one else can make for us, which no one can spare us, for our wisdom is the point of view from which we come at last to regard the world.

Marvin Minsky on MICROWORLDS

In doing this (working in the world of children's blocks), we'll try to imitate how Galileo and Newton learned so much by studying the simplest kinds of pendulums and weights, mirrors and prisms. Our study of how to build with blocks will be like focusing a microscope on the simplest objects we can find, to open up a great and unexpected universe. It is the same reason why so many biologists today devote more attention to tiny germs and viruses than to magnificent lions and tigers. For me and a whole generation of students, the world of work with children's blocks has been the prism and the pendulum for studying intelligence. *In science, one can learn the most by studying what seems the least.*

Overview

The text you are currently reading represents a first course in computer programming that features the Java programming language. More precisely, it substantially represents the *laboratory component* of the course, while only nominally representing the *presentational component* of the course, and merely alluding to the *programming component* of the course. What makes this course somewhat distinctive is that the approach is grounded in a number of cognitively oriented thematic threads, namely *educational microworlds*, *distributed cognition*, and elements of *the learning sciences*.

Orientation of the Text

One of Seymour Papert's many catchy observations is that *in order to think about thinking you have to think about thinking about something*. The same basic idea applies to the process of learning to program. You need to write programs *about* something, in the context of some domain, so that you can think about your programming and reflect deeply upon the wide range of phenomena surrounding the programming of computers. In this text a number of domains that are closely associated with creative acts will serve as computational contexts for programming activities and reflections. One of the domains is *music*. Another of the domains is *nonrepresentational art*. A third domain involves *objects of chance*. Modest *computational learning environments* associated with each of these domains have been crafted in support of this course. A **computational learning environment** is simply a collection of computational objects that are thematically related, and which collectively afford opportunities to computationally explore domain specific ideas in particularly productive ways. By grounding your study of computer programming in these domains, particularly music and nonrepresentational art, you will be more likely to wind up viewing computer science as a creative activity than you would if your learning were tied to the fields more traditionally associated with first courses in computer programming, the STEM fields of science, technology, engineering, and math. There is a move afoot to add an A to STEM. The A in STEAM is for the arts! There is nothing new about the notion

that the arts can fuel the fire of innovation in science, technology, engineering, and math. The MIT Media lab was founded on this premise. A number of colleges and universities embrace this idea (MIT, NJIT, and Drexel are among the leaders in doing so), and various projects are dedicated to the proposition (for example, EarSketch). Yet there hardly appears to be a tidal wave of enthusiasm for flavoring STEM curricula, or even first computer science courses, with the arts. The course of study determined by this text is clearly sympathetic to those who are championing STEAM in educational circles.

Structure of the Text

The course for which this text was written is something of an inversion to the norm, in that its cornerstones are *experiences* in the laboratory rather than *explanations* in the lecture. Both are essential, but in a significant sense the laboratory experiences are intended to drive the course. What you do with this laboratory manual will determine, to a large extent, the degree to which you actually realize a *meaningful* first course in computer science. If you merely read it, you won't get much out of the course. If you fully engage in the laboratories, which requires faithfully attending lectures and studiously sorting out the material presented during the lectures, in order to position yourself to be successful with the labs, you will probably learn something substantial about the nature of computer programming. If, in addition, you tackle each programming assignment like you mean it, and craft a program/demo archival work site to be proud of, you could very well find that you will have taken a first step on the road to becoming a computer scientist!

This text is structured as a sequence of *laboratories* separated by references to *presentations* (references to lectures), all preceded by an *entrance* and followed by an *exit*. The laboratory parts, the essential parts of this text, are intended to be held in hand. This will facilitate your engagement in the laboratory activities. In this manual, the references to presentations are meant to remind you that you really will be missing out on essential material should you miss a lecture. The classroom *experience* of declarative lectures laced with procedural demonstrations, framed by all of the cognitive phenomena surrounding these knowledge oriented activities, is simply not something that you can make up.

The bipartite nature of this text, the inclusion of *labs* and the referencing of *presentations*, is represented explicitly in the table of contents. The thematic threads that permeate this text (and the course), on the other hand, find expression in a much more implicit manner. The next three sections of this *Entrance* are presented in an effort to prepare you to appreciate these thematic threads as you work your way through the course, especially when you are doing the labs and the programming challenges.

Microworlds

A **microworld** is a limited collection of objects in a limited environment that can be manipulated in a limited number of ways. Microworlds, being rather small in scope, can fairly easily be tailored to suit particular needs. Microworlds that are easy to understand without much explicit instruction, yet which are rich enough to be interesting, can be effective educational tools. In this text, the term *microworld* will mean *computational educational microworld*, which simply means that the microworlds considered have been designed with learning in mind and will manifest as virtual worlds. For most practical purposes, the term *microworld* can be used synonymously with the phrase *computational learning environment*. Interestingly, it is considered sport, among some (skeptics of AI, in particular), to criticise microworlds because the don't *scale up*. Yet the critiques generally fail to acknowledge, much less appreciate, the fact that microworlds are not so much intended to scale up as they are intended to help you, and your ideas, scale up!

Two microworlds will take center stage in this course, one featuring simple geometric shapes, and the other featuring basic musical notes. The former is called the Nonrepresentational Painting World, or NPW. The latter is called the Modular Melody World, or MMW. A third microworld that features coins and dice, called the Chance World, will make occasional appearances throughout the course.

Distributed Cognition

According to Roy Pea (1997), **distributed cognition** "is the conception of cognition as something accomplished through collaborative interactions involving people and artifacts, as opposed to something possessed by individuals in isolation." Most definitions of the concept are more or less consistent with this one. Some perspective, and some elaboration, will help to make clear how this notion plays a role in computer science, and how it will be featured in the course for which this text was written.

Cognitive science is closely associated with the premise that cognition can best be understood in terms of *representations* and *transformations* of those representations. This is the **computational/representational assumption** that serves to provide a substantial element of cohesion to the field. *Cognitive science* is also closely associated with the idea that the mind can best be studied by approaching it from a diversity of disciplinary perspectives, and then endeavoring to integrate the findings that accrue. This is the **interdisciplinary assumption** which adds breadth to the field. These two foundational assumptions can be viewed as defining characteristics of **traditional cognitive science**. Almost from the start, a number of individuals within the contributing disciplines to cognitive science have been highly critical of the computational/representational assumption, suggesting that is is much too limiting (Dreyfus, 1979; Searle, 1980; Winograd & Flores, 1987).

In words that I more or less lifted from Salomon (1997), but then heavily edited: ≪The proponents of *distributed cognition* don't dispute the computational/representational assumption, per se. Rather, they take issue with the *location* that traditional cognitive scientists tend to ascribe to the representations and transformations that are said to form the basis of cognition. In contrast to the theoretical stance associated with *traditional cognitive science*, that cognition is in the *head*, proponents of *distributed cognition* adopt the theoretical view that cognition takes place within a *system* that includes humans and tools. In the *traditional cognitive science framework*, cognition is considered to be a *state of being* that tends to be described in terms of a rich mix of mental constructs. In the *distributed cognition framework*, cognition is viewed as an *emergent property* of interaction among components of the system. In other words, **distributed cognition** adopts a perspective for investigating cognitive phenomena according to which cognition is equated with representation based interactions among the people and the artifacts that make up a system.≫

The ideas associated with distributed cognition were originally proposed by Edwin Hutchins (1995). Hutchins, a cognitive anthropologist, was a keen observer of navigation. He observed people responsible for navigating both airplanes and ships. He was struck by how information was *distributed* among people and artifacts, and how no *single person* was in a position to navigate the vehicle. One of Hutchins' key insights is that the very *nature* of a problem is changed when it is considered through the lens of distributed cognition. Donald Norman, a colleague of Hutchins, adroitly made his own contributions to the theory of distributed cognition, expertly discussed the framework in popular texts, and succeeded in pointing the way towards reconceiving the foundational elements of Human-Computer Interaction (HCI) in terms of distributed cognition. Among Norman's most significant theoretical contributions was his articulation of the nature and role of *cognitive artifacts*. A **cognitive artifact** is essentially a man-made tool that is designed to enhance cognition. "The power of a cognitive artifact comes from its function as a representational device" wrote Norman (1991). He then went on to define cognitive artifact in *representational* terms as "an artificial device designed to maintain, display, or operate upon information in order to serve a representational function."

A *to do list* is a cognitive artifact. Such a list effectively enhances your memory. From another perspective, however, the list merely changes the nature of what you do from referencing your memory to maintaining and checking a list. A *GPS* is a cognitive artifact. It effectively enhances your ability to get from here to there. On the other hand, neither your knowledge of navigation nor your sense of direction are improved by the GPS system. Clearly it changes the nature of your task, not only the rational aspect of the task which amounts to searching for a desired route through a landscape of sometimes hard to find landmarks, but also the emotional aspect of the task which tends to be transformed from somewhat stressful ordeal to rather relaxed journey! *LaTeX* is a cognitive artifact that I used for generating this text. Merely the fact that the table of contents references pages correctly is an indicator that I can do better work with LaTeX than without it.

How is any of this relevant to the processes of learning to program computers? You will be using a range of cognitive artifacts in support of your programming activities. IntelliJ, the *integrated development environment (IDE)* that is featured in this course is an excellent example of a cognitive artifact, one that powerfully reflects Norman's representational definition of the concept. It will help you to be a much more productive Java programmer than you would otherwise be. The microworlds (NPW and MMW) are domain specific cognitive artifacts that will help you to do graphics programming and sonic programming. Additionally, you will be using certain information processing tools that will *indirectly* support your programming activities by enhancing your skills with respect to learning. These information processing tools – search tools, site development tools, social media tools – are also cognitive artifacts.

Having said all of this about distributed cognition, it is important to emphasize, as Gavriel Salomon (1997) does in "No distribution without individuals' cognition: a dynamic interactional view," that it is vital to value both *individual cognition* and *distributed cognition*. To effectively engage in computer programming, you want to (1) cultivate a mix of well developed mental models, and (2) develop an ability to become one with powerful tools and systems. Furthermore, it is worth noting that while some interactions with cognitive artifacts may fail to change the way we think, by merely changing the nature of the problem at hand, as Hutchins so insightfully observed, other interactions with cognitive artifacts may significantly change the way we think. In fact, computer programming languages and computational microworlds are cognitive artifacts of this second kind, the kind that leave some sort of *cognitive residue* behind in the wake of intellectual partnership.

The Learning Sciences

One body of knowledge that is increasingly finding traction among educators, especially those in higher education, goes by the name of *the learning sciences*. The term **learning sciences** refers to a *system of principles* that pertain to learning, along with investigations into the validity and utility of the principles, and explorations of interactions among the principles. There is no one universally agreed upon set of principles, but here is a list of those learning science principles that figured most prominently in the conception and construction of this text:

- **Constructionist Principle** An extension of Piaget's constructivism − the theory that learning involves the building of knowledge structures within the individual mind − which adds (1) the idea that "this happens especially felicitously in a context in which the learner is consciously engaged in constructing a public entity" (Papert, 1980), and (2) a "more distributed view of instruction, one where learning and teaching are constructed in interactions between the teacher and students as they are engaging in design and discussion of learning artifacts" (Kafai, 2006).
- **Deep Learning Principle** Education is best accomplished by privileging engagement over explanation, uncoverage over coverage, questioning over answering, reflection over reaction, representation over information, and process over product.
- **Project-Based Learning Principle** Deep learning accrues as a side-effect of engagement in an incremental, holistic process of artifact creation in response to the consideration of a substantial problem of interest to the learner.
- **Learner-Centered Design Principle** Favor bridging the "gulf of expertise" over the "gulf of execution" and the "gulf of evaluation". That is, place emphasis on scaffolding which affords opportunities to enhance understanding by bridging the conceptual distance between a novice and an expert in the domain of interest, rather than on tools or methodologies that merely ease the performance of tasks (Quintana, Shin, Norris, & Soloway, 2006).
- **Imagery Principle** Educators need to search for ways in which the power of imagery (e.g., effortless structural interpretation) can be used to support learning, creativity, and reasoning (Schwartz & Heiser, 2006).
- **Inscription Principle** Students learn by doing and by thinking about what they have done. Creating external representations of one's thoughts in some sort of inscription system for reflecting upon one's thinking and sharing one's thoughts with others is of central significance to deep learning (Pea, 1993).
- **Distributed Cognition Principle** Cognition is something accomplished through collaborative interactions involving people and artifacts rather than something possessed by individuals in isolation (Hutchins, 1995).

You will find unconcealed traces of these principles lurking throughout the course that this text supports, throughout its *labs* and its *presentations* and its *programming challenges*. Where do they come from? They derive from the work of some of the great thinkers about learning and education, including L. S. Vygotsky, Maria Montesori, John Dewey, Jean Piaget, and Seymour Papert. The list that I compiled is just *one possible organization* of a *selection of lasting ideas about learning* into a *system of principles*. The *names* that I determined to give the principles are merely intended to make them a bit more sticky in the mind.

Tips on Learning to Learn

The aforementioned principles informed my crafting of this course, the *labs*, the *presentations*, and the *programming challenges*. That is, they informed my efforts at *teaching* the material, by which I mean, to riff on Einstein, *setting up conditions in which my students might learn*. On the other side of the teaching/learning equation, here are just a few ideas that you might like to bear in mind as you work through this text, ideas about *learning* and *thinking* that may resonate with you:

- *The "3 Rs" of Learning* – Guy Claxton Claxton (2000) references three potential habits of mind that he believes are the mark of a good learner. The Rs stand for *resourcefulnes*, *resilience*, and *reflection*. **Resourcefulness** is the ability to deal with challenging problems or situations in inventive ways. **Resilience** is the ability to persist in pursuit of a goal in spite of uncertainty, confusion, obfuscation, or other difficulties. **Reflection** is the act of looking at a thought from a strategic point of view with an eye towards confirmation, refutation, or reformulation. (For Dewey (1933), *reflective thinking* has connotations of being grounded in experience, of evaluating the quality of the thought, and of vigilantly reshaping thoughts in potentially productive ways.)
- *Mindfulness* – One potential habit of mind that has been getting quite a bit of press lately is *mindfulness*, as championed by Ellen Langer. A **mindful approach to thinking**, she suggests, involves three things: a search for new ways to classify knowledge, a disposition to appropriate new information, and an appreciation of multiple perspectives (Langer, 1998, p. 4). The proponents of mindfulness believe that approaching cognitive activities mindfully is a key to empowering learning.
- *Metacognition* – The term **metacognition** refers to thinking about thinking. In metaphorically eloquent words that are a good fit for a text on learning to program, M. Martinez (2010, p. 143) asks: "How is it possible to establish higher-order thinking as a habit - to build metacognition into our mental software as a background application that runs continuously?" If you are serious about learning, you will do your very best to find an answer that works for you!
- *Mindset* – Carol Dweck (2007), based on decades of research, contrasts the **fixed mindset** with the **growth mindset**. By distancing yourself from the former, which tends to stifle your ability to learn by incorporating the notion that having to work hard simply betrays intellectual inadequacies, and cultivating the latter, which champions the belief that hard work is a catalyst for meaningful growth, you are more likely to become the person, thinker, programmer that you would really like to be. (Dweck makes a compelling case for the *growth mindset* in some of her 10 minute Youtube videos.)

How to Use this Text

This laboratory manual will help to guide you through the acquisition of some basic knowledge of computer programming in Java using the IntelliJ integrated development environment. The labs are an *integral part* of the course. Some of them introduce new material that will be elaborated during classroom presentations. Some of them serve to clarify ideas presented during the classroom presentations. Some of them constitute the start of a programming assignment.

$\Longrightarrow$ **The labs are, with the exception of just a few rather short labs, designed to be started during your formal laborartory period, and then completed on your own.**

Having the hard copy text of a lab with you will substantially enhance your laborartory experience, compared with trying to read it from on line. So please be sure to bring the lab manual with you to each laboratory class. You

should be answering the occasional questions posed right in the manual. You should be making notes in the manual about questions that arise in your mind as you work through the manual. You should be keeping your place in the sequences and subsequences of tasks that define the laboratory activities by making marks in appropriate ways on the pages of the manual. In short, you should be making your lab manual "your own"!

Not only do the labs tend to extend beyond the temporal scope of a lab period, but they extend beyond the temporal scope of the semester. By saying this I am referring to the fact that there is at least one more lab in the manual than will fit comfortably into the semester. Maybe two. Maybe three. This is by design. No worries. Any "extra" labs will be featured prominently in classroom discussions. Moreover, they will serve as the basis of my first answer to the question frequently asked by students at the end of the course: "What might I do in order to prepare for the subsequent CS2 course?"

Technical Content Represented in this Text

Lest all of these preliminaries obscure the fact that this text really does support a CS1 course, the following partial list of technical terms and phrases that you will find in this text, presented in no particular order, is intended to serve as a reminder!

▷ array ◇ ArrayList ◇ LinkedList ◇ instance ◇ class ◇ object ◇ binding ◇ Java ◇ Emacs ◇ IntelliJ ◇ unix ◇ html ◇ css ◇ method ◇ argument ◇ parameter ◇ constant ◇ type ◇ variable ◇ int ◇ double ◇ boolean ◇ String ◇ if ◇ while ◇ for ◇ map ◇ filter ◇ reduce ◇ `String.join`◇ abstract class ◇ assignment statement ◇ Standard Input Stream ◇ Standard Output Stream ◇ wigit ◇ fully parenthesized expression ◇ circumscribing circle ◇ inscribing circle ◇ circumscribing square ◇ inscribing square ◇ evaluation ◇ interpreter ◇ recursion ◇ parser ◇ recognizer ◇ dialog box ◇ error handling ◇ loop forever ◇ break ◇ multiway conditional ◇ random number generator ◇ command ◇ function ◇ stepwise refinement ◇ abstraction ◇ conditional execution ◇ length ◇ indexOf ◇ substring ◇ equals ◇ equalsIgnoreCase ◇ class ◇ extends ◇ implements ◇ string concatenation ◇ rubber ducking ◇ exceptions ◇ system properties ◇ file processing ◇ full path name ◇ array element referencing ◇ programming by analogy ◇ type casting ◇ generics ◇ searching ◇ sorting ◇ constructor ◇ instance variables ◇ accumulator ◇ referencer ◇ stream ◇ lambda ◇ scoping ◇ local with respect to ... ◇ global with respect to ... ◇ "mechanical" translation ◇ deterministic ◇ nondeterministic ◇ pseudocode ◇ interface ◇ stub ◇ implementing an interface ◇ parallel arrays ◇ sequential search ◇ graphics processing ◇ sonic processing ◇ incremental programming ◇ symbolic computation ◇ scanner ◇ interpreter ◇ self-similar set ◇ fractal ◇ L-System ◇ algorithm ◇ invariance ◇ reuse ◁

2 Lab 1: Hello World! Hello You!

William James on WISDOM

The art of being wise is the art of knowing what to overlook.

Overview

In this lab you will establish and run two very simple programs. The first is loosely referred to as the "hello world" program. This opener is purely text-based. The second is a variant of the first which features a *widget* – a computational component with a graphical representation.

Why do it?

As you work through this lab you will:

1. Get acquainted with IntelliJ, the standard computer programming environment for this particular course.
2. Establish and run simple Java programs in IntelliJ.
3. Hone your skills with respect to *methodically* executing sequences of tasks.

Task 0: Get set up on the CS department machines

1. Log on to a sanctioned machine. Use your Laker ID for your username and the password provided in class.
2. Change your password ...
   (a) Open a terminal by right clicking on the desktop and picking `Open Terminal`.
   (b) Type `yppasswd` at the prompt.
   (c) Enter your old password when asked for it. It will not be visible as you type.
   (d) Enter your new password when asked for it. It will not be visible as you type.
3. Once you've returned to the prompt you may close the terminal.

Task 1: Prepare to do some Java programming in IntelliJ

1. Get into IntelliJ ...
   (a) Search for IntelliJ on your machine, unless you can spot it just lying around somewhere.
   (b) Launch it!

2. Establish a new project ...
   (a) When the *Welcome to IntelliJ IDEA* window appears, choose `Create New Project`.
   (b) On the *New Project* form that appears on the screen ...
      i. Be sure that Java is selected on the left side of the screen and click `Next`.
      ii. Choose not to use a template for our project and click `Next` again.
      iii. Type `CS1` into the *Project Name* field.
      iv. Click `Finish`.

Task 2: Establish and run the traditional starter program

1. Create a package ...
   (a) On the left side of the screen, click the arrow next to CS1 to expand it.
   (b) Right click on the `src` folder and create a new `Package`. A package is a way to keep parts of your Java program organized.
   (c) In the window that appears, call your package `greetings` and click `OK`.
2. Create a source program ...
   (a) Expand the the `src` folder if necessary.
   (b) Right click on the `greetings` package and create a new `Java Class`.
   (c) On the *New Java Class* form that appears ...
      i. Type `HelloWorld` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
   (d) Modify the source program template so that it matches the following:

```
/*
 * Traditional starter program.
 */

package greetings;

public class HelloWorld {

   public static void main(String[] args) {
       System.out.println("Hello world!");
   }

}
```

3. Run the program ...
   (a) Select `Run 'HelloWorld.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Observe that `Hello World!` appears among the information the *Output* window.

Task 3: Establish and run the nontraditional variant of the starter program

1. Create a source program ...
   (a) Right click on the `greetings` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `HelloYou` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
   (c) Modify the source program template so that it matches the following:

```
/*
 * Variant of the traditional starter program that features a widget.
 */

package greetings;

import javax.swing.JOptionPane;

public class HelloYou {

   public static void main(String[] args) {
       String name = JOptionPane.showInputDialog(null, "Who are you?");
       System.out.println("Hello, " + name + "!");
   }

}
```

2. Run the program ...
   (a) Select `Run 'HelloYou.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Enter your name into the *Input* dialog box that appears.
   (c) Observe that the appropriate text appears among the information the *Output* window.

Task 4: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

3 Presentation: Microworlds, Distributed Cognition, Learning to Learn

This material is presented in real time during course lectures.

4 Lab 2: Hello Painter! Hello Composer!

Carl Jung on THE CREATIVE MIND

The creation of something new is not accomplished by the intellect but by the play instinct acting from inner necessity. The creative mind plays with the objects it loves.

Something to think about

Learning can be viewed as a two stage process in which you (1) gain some experience, and (2) endeavor to make sense of the experience. As you engage in this lab, which affords you an opportunity to get acquainted with the *Nonrepresentational Painting World* and the *Modular Melody World*, please do your best to appreciate this perspective on learning.

Overview

One premise of this course is that it tends to be more fun to take, and more fun to teach, if some interesting computational objects, housed in computational learning environments, are incorporated into the course. With this premise in mind, a *graphical microworld* and a *musical microworld* are introduced in this lab.

The Nonrepresentational Painting World (NPW) contains functionality for creating and manipulating a variety of shapes. It also contains functionality for creating painters that can render (draw/paint) the shapes on a virtual canvas. In this lab you are asked to create two images in the context of the NPW.

The Modular Melody World (MMW) affords access to simple note objects, and to composer objects that make use of a dedicated note object to assist you in laying down coherent sequences of musical notes. The note objects, whether stand alone or composer controlled, can be rendered sonically, visually, or chromesthetically. In this lab you will be asked to create a melodic fragment with a stand alone note object, to establish a *listening* program that will enable you to get acquainted with the most basic modular melodic sequences of MMW, and to create a melodic sequence by enlisting the aid of a composer object.

Note: This lab is sure to run a bit long! It is not expected that you will finish it during the lab hour. Please finish this on your own prior to your next week's lab hour. You might think of the task of completing this lab on your own as a preliminary programming assignment, since the programming assignments are activities that your are expected to do on your own.

Why do it?

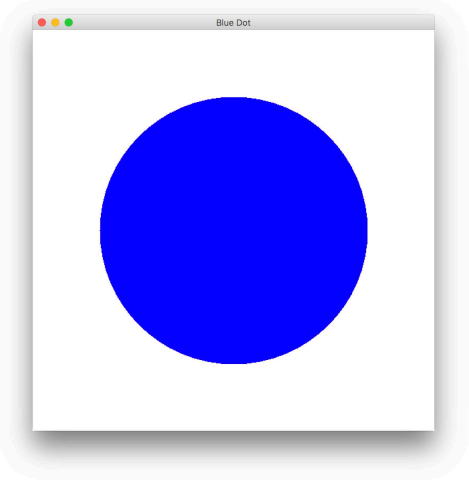
As you work through this lab you will:

1. Install some `.jar` files in your `CS1` project library, files that contain programs that you will run.
2. Create and use computational objects in Java.
3. Engage in some creative computational activities.
4. Learn how to write a program by starting with an existing program that does something similar to what you want your new program to do.
5. Gain familiarity with the Nonrepresentational Painting World.
6. Gain familiarity with the Modular Melody World.

Task 1: Install the software that implements the computational microworlds (NPW and MMW) in the library of your `CS1` project

1. Get a browser going.
2. Find your way to the following page:
   `http://danielschlegel.org/wp/teaching/csc212-spring-2020/software/`
3. Download three files. These files contain software that you will use to create images and melodic sequences.
   (a) Download the *simple painter* code (the `SimplePainter.jar` file) from the *Java Microworld APIs* area of the page. **Important**: Please perform the download in the following way:
      i. *Right click* on the link.
      ii. Select the `Save Link As ...` option.
      iii. Save the file to your *home* directory, or to a special directory that you create for the purpose of storing these three files.
   (b) Download the *simple composer* code (the `SimpleComposer.jar` file) from the *Java Microworld APIs* area of the page. **Important**: Please perform the download in the manner prescribed for the simple painter file.
   (c) Download *JFugue* (the `jfugue-4.0.3-with-musicxml.jar` file) from the *Java Microworld APIs* area of the page. **Important**: Please make use of the same downloading procedure.
4. Add the files to the *External Libraries* folder of the `CS1` project:
   (a) Return to IntelliJ.
   (b) Select, if necessary, the `CS1` project.
   (c) From the *File* menu choose `Project Structure...`
   (d) On the left side of the window which appears, choose `Modules`.
   (e) Click the `Dependencies` tab.
   (f) At the bottom of the window, near the center, click the `+` button. Select the `JARs or directories...` option. With the assistance of the widget that appears, find your way to the `SimplePainter.jar` file that you recently downloaded, and then get it.
   (g) At the bottom of the window, near the center, click the `+` button. Select the `JARs or directories...` option. With the assistance of the widget that appears, find your way to the `SimpleComposer.jar` file that you recently downloaded, and then get it.
   (h) At the bottom of the window, near the center, click the `+` button. Select the `JARs or directories...` option. With the assistance of the widget that appears, find your way to the `jfugue-4.0.3-with-musicxml.jar` file that you recently downloaded, and then get it.
   (i) Click `OK` in the *Project Structure* window.
   (j) If you haven't yet done so, look to see if the *External Libraries* folder contains the three files.

Task 2: Write and run a program to generate an image consisting of a blue dot



---

1. Create a package ...
   (a) On the left side of the screen, click the arrow next to CS1 to expand it.
   (b) Right click on the `src` folder and create a new `Package`.
   (c) In the window that appears, call your package `npw` and click `OK`.
2. Create a source program ...
   (a) Right click on the `npw` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `BlueDot` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
   (c) Modify the source program template so that it matches the following:

`BlueDot` Program

```
/*
 * Program to paint a blue dot in the context of the Nonrepresentational
 * Painting World, NPW.
 */

package npw;

import java.awt.Color;
import javax.swing.SwingUtilities;
import painter.SPainter;
import shapes.SCircle;

public class BlueDot {

    // THE SOLUTION TO THE BLUE DOT PROBLEM
```

```
    private void paintTheImage() {
        SPainter klee = new SPainter("Blue Dot",600,600);
        SCircle dot = new SCircle(200);
        klee.setColor(Color.BLUE);
        klee.paint(dot);
    }

    // REQUIRED INFRASTRUCTURE

    public BlueDot() {
        paintTheImage();
    }

    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                new BlueDot();
            }
        });
    }

}
```

---

3. Run the program ...
   (a) Select `Run 'BlueDot.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Observe the output, the blue dot in the window that appears.
   (c) Close the window containing the blue dot.

Task 3: Write and run a program to generate the first several notes of a well-known melody using a *lone note*

1. Create a package...
   (a) Right click on the `src` folder and create a new `Package`.
   (b) In the window that appears, call your package `mmw` and click `OK`.
2. Create a source program...
   (a) Right click on the `mmw` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `Dorothy` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.

(c) Modify the source program template so that it matches the following:

`Dorothy` **Program**

```
/*
 * Name that tune!
 */

package mmw;

import note.SNote;

public class Dorothy {

    public static void main(String[] args) {
        SNote note = new SNote();
        note.text();
        note.x2(); note.play();
        note.rp(7); note.play();
        note.s2(); note.lp(); note.play();
        note.lp(2); note.s2(); note.play();
        note.rp(); note.play();
        note.x2(); note.rp(); note.play();
        note.rp(); note.play();
        System.out.println();
    }

}
```

---

3. Run the program ...
   (a) Select `Run 'Dorothy.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Observe the output, the textual representation of the notes, at least. If you can do so, give a listen. Can you name that tune?

Task 4: Write and run a program to listen to the *Basic* modular melodic sequences

Eight of the modular melodic sequences inherently available in the MMW are classified as *Basic* sequences. This task invites you to write a program that will allow you to listen to the sequences, provided you have a way to hear the machine's sonic output.

1. Create a source program...
   (a) Right click on the `mmw` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `BasicsListener` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.

(c) Modify the source program template so that it matches the following:

`BasicsListener` **Program**

```
/*
 * Program to check out (view and possibly listen to) the eight melodic
 * sequences classified as "Basic" sequences in the Modular Melody World
 */

package mmw;

import composer.SComposer;

public class BasicsListener {

    public static void main(String[] args) {
        SComposer c = new SComposer();
        c.text();
        System.out.println("c.mms1 ..."); c.mms1(); space(c);
        System.out.println("c.mms2 ..."); c.mms2(); space(c);
        System.out.println("c.mms3 ..."); c.mms3(); space(c);
        System.out.println("c.mms4 ..."); c.mms4(); space(c);
        System.out.println("c.mms5 ..."); c.mms5(); space(c);
        System.out.println("c.mms6 ..."); c.mms6(); space(c);
        System.out.println("c.mms7 ..."); c.mms7(); space(c);
        System.out.println("c.mms8 ..."); c.mms8(); space(c);
        c.untext();
    }

    private static void space(SComposer c) {
        c.untext(); c.rest(2); c.text();
    }

}
```

---

2. Run the program. If you can hear the sound generated by the machine you are working on, good! If not, perhaps you can imagine it from the textual output provided.
   (a) Select `Run 'BasicsListener.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Observe the output, the textual representation of the notes, for sure. The sounds, if possible.

Task 5: Develop a program to generate a simple melodic sequence from modular melodic sequences using a *simple composer*

1. Create a source program...
   (a) Right click on the `mmw` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `Melody` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
   (c) Modify the source program template so that it matches the following:

`Melody` Program

```
/*
 * A sequence of simple modular melodic sequences.
 */

package mmw;

import composer.SComposer;

public class Melody {

    public static void main(String[] args) {
        SComposer c = new SComposer();
        c.text();
        c.mms5();
        c.rp(); c.mms5(); c.lp();
        c.lp(); c.mms5(); c.rp();
        c.mms5();
        c.untext();
    }

}
```

---

2. Run the program. If you can't hear the sound on the system you are working on, no worries. The text command causes the notes to be rendered textually, so you should be able to determine whether or not your program is working correctly.
   (a) Select `Run 'Meolody.main()'` from the menu that appears when you *right click* somewhere in the area that is displaying the source code.
   (b) Observe the output, the textual representation of the notes, for sure. The sounds, if possible.
3. Add a bit to the program. Do this by means of a *copy-paste-edit* operation.
   (a) *Copy* the following four lines of the program:

```
c.mms5();
c.rp(); c.mms5(); c.lp();
c.lp(); c.mms5(); c.rp();
c.mms5();
```

(b) *Paste* them, right after the four lines that you copied, just before the `c.untext()` command that constitutes the last statement of the `main` method. You will then have two adjacent occurrences of the same sequence of four statements.

(c) *Edit* the second of the two identical sequences of four statements so that it looks like this:

```
c.mms7();
c.rp(); c.mms8(); c.lp();
c.lp(); c.mms7(); c.rp();
c.mms8();
```

4. Run the program once again, and observe the longer sequence of notes.

Task 6: Write and run a program to generate the Target logo in the NPW

Please note that the diameter of the large red defining circle is three times that of the small red defining circle, and that the diameter of the white defining circle is twice that of the small red defining circle.

---

1. Create a source program from the extant `BlueDot` program, but then change it to paint the Target logo ...
   (a) Right click on the `npw` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `Target` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
   (c) Using the `BlueDot` program as a model, and using the specifications of NPW functionality as reference material (see Appendix 1), write a program to paint the Target logo. In doing so, please proceed in the following manner:
      i. Replace all of the text in the `Target` buffer with all of the text in the `BlueDot` buffer. (*Copy and paste is your friend!*)
      ii. Edit the comment at the head of the file to reflect the fact that you will be painting the Target logo rather than a blue dot.
      iii. Replace all occurrences of `BlueDot` with `Target`. (There are three such occurrences.) Also, replace the title of the painter's canvas appropriately.
      iv. Change the method that actually does the painting (the `paintTheImage` method) so that it paints the Target logo rather than the blue dot. **Note that you may use more than one `SCircle` object.**

2. Run the program. If it does not work, fix it, and repeat this item.

Task 7: Reflection

1. How might you paint the Target logo with just *two* `SCircle` objects? How would your current `paintTheImage` method change?

2. How might you paint the Target logo with just *one* `SCircle` object? What changes would you need to make to the order of the lines of code in order to complete the task with this constraint?

3. Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

5 Presentation: Using Objects - Painters and Composers

This material is presented in real time during the course lectures.

6 Lab 3: Establishing a CS1 Work Site

Samuel Johnson on THE ACTIVE MIND

When the eye or the imagination is struck with any uncommon work, the next transition of an active mind is to the means by which it was performed.

Overview

This lab is designed to help you to *commence* the activity of building a Web site dedicated to presenting your work in this course. In operational terms, this lab engages you in processes of creating directories, downloading files, creating files, distributing files to appropriate directories, and repeatedly editing/viewing files in a browser.

Please bear in mind that the idea is merely for you to *strive* to complete the tasks specified in this lab during the lab period. It is *not expected* that you will complete all of them during the allocated time. Please complete those that you do not manage to finish during the lab time within the following week.

Why do it?

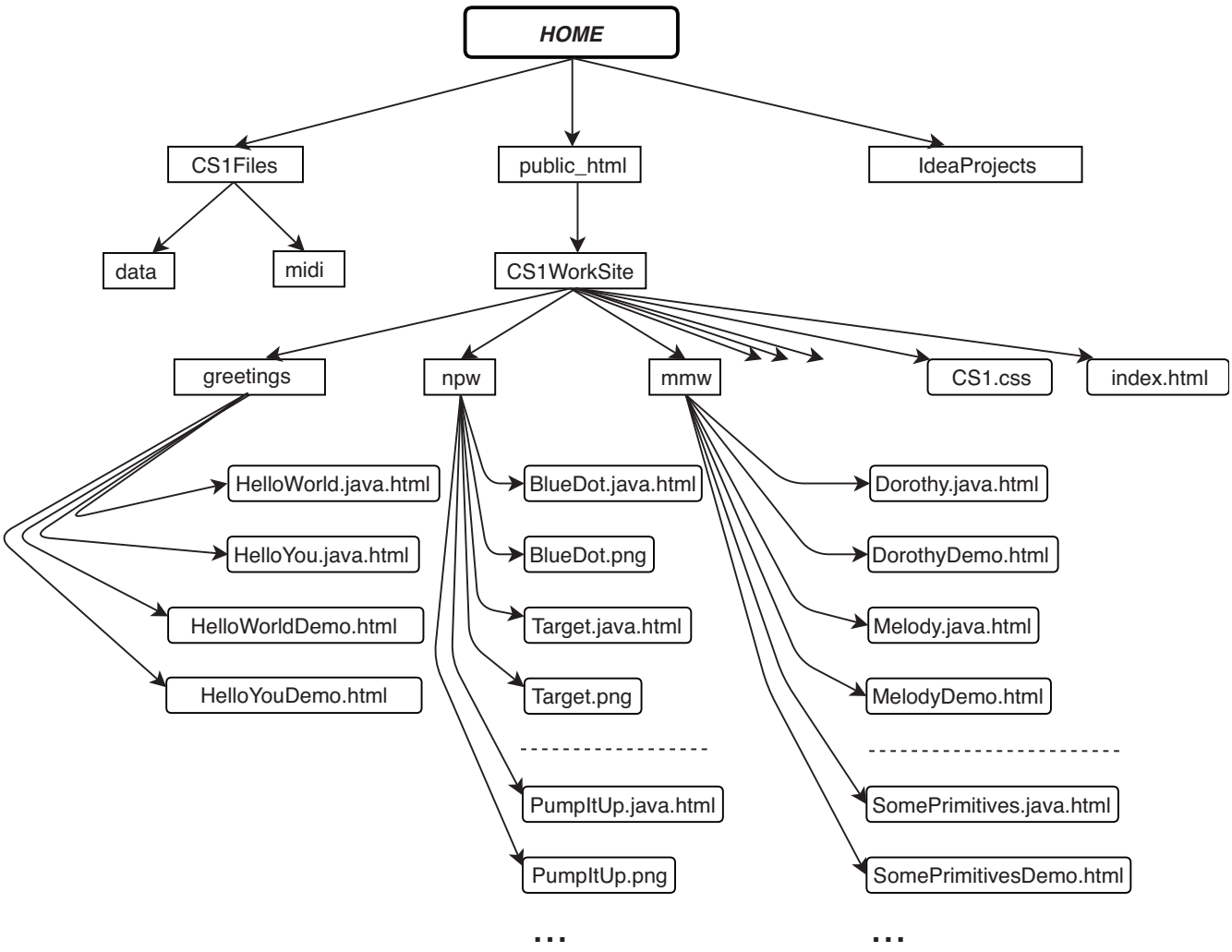
To engage in computer programming effectively, it is essential to (1) have a sense of the environment in which you are operating, and (2) have at least a modest command of a selection of tools which are used to operate within, and occasionally tailor, that environment. As you work through this lab you will develop a sense for the environment, and a bit of knowledge pertaining to the operating system, a texted editor, and a Web browser.

You will also commence to build a Web site by:

1. Creating a directory structure for your work site.
2. Downloading files to particular locations within your newly created directory structure.
3. Engaging in a constructionist process of:
   (a) Editing `.html` files and a `.css` file using the `Emacs` text editor.
   (b) Viewing `.html` files in a browser.
   (c) Saving `.java` files as `.html` files to particular locations within your Web site work area.
   (d) Creating and saving *image files* to particular locations within your Web site work area.
   (e) Creating and saving *Standard IO demo files* to particular locations within your Web site work area.

Required directory structure

Please do your best to make the following image sticky in your mind. The image suggests the directory structure that you should use to house files associated with this course.



Terminal Mini Manual

In this lab you will make considerable use of the *Terminal* window. The text gives instructions that includes the commands you need. As you come across commands with which you are unfamiliar, write them down in this space, and on the next page, along with a short description of what the command does and an example of how to use the command. In this way, you are making a "mini manual" for using the *Terminal* window.

Task 1: Get ready to do some work

1. Log on to a sanctioned machine.
2. Open a *Terminal* window.
3. Open the *Emacs* text editor. If faced with more than one, be sure to choose the GUI version.
4. Open *IntelliJ*.
5. Open a Web browser, like *Firefox* or *Chrome*.

Task 2: Add some folders to your directory structure

As you work through this task, it will benefit you to be mindful of the relationship between the commands that your are issuing and the directory structure depicted.

1. In the *Terminal* widow, make sure that you are in your home directory by issuing two operating system commands, and observing the operating system response.
   (a) Issue the "go home" version of the *change directory* command by typing `cd` followed by the Enter key.
   (b) Issue the *print working directory* command by typing `pwd` followed by the Enter key.
2. Create a folder for your Web work. This folder must have a particular name in order for the CS servers to, eventually, allow you to make your work available for all to see on the Web.
   (a) Issue the *make directory* command to create the `public_html` folder within your home directory by mindfully thinking underscore (rather than dash) and typing: `mkdir public_html` (followed by the Enter key)
   (b) Issue the *list files* command by typing `ls` (that is "elle" "esss") followed by the Enter key. Observe that your folder was created!
3. Change directories so that you are working within your `public_html` directory.
   (a) Type: `cd public_html` (followed by the Enter key)
   (b) Just to be sure that you are where you want to be, issue the command to print your working directory, `pwd`, and observe.
4. Create a folder within your `public_html` directory for your course work site. Be careful to name it as specified.
   (a) Issue the *make directory* command by typing: `mkdir CS1WorkSite`
   (b) Issue the *list files* command by typing `ls` (that is "elle" "esss") followed by the Enter key. Observe that your folder was created!
5. Create a folder within your *home directory* for the storage of miscellaneous course related files. Be careful to name it as specified.
   (a) Issue the "go home" version of the *change directory* command by typing `cd` followed by the Enter key.
   (b) Just to be sure that you are where you want to be, issue the command to print your working directory, `pwd`, and observe.
   (c) Issue the *make directory* command to create the folder by typing: `mkdir CS1Files`
   (d) Issue the *list files* command by typing `ls` (that is "elle" "esss") followed by the Enter key. Observe that your folder was created!
6. Change directories so that you are working within your `CS1Files` directory.
   (a) Type: `cd CS1Files`
   (b) Just to be sure that you are where you want to be, issue the command to print your working directory, `pwd`, and observe.
7. Create a folder called `data` within your `CS1Files` directory. Check to see that you were successful.
8. Create a folder called `midi` within your `CS1Files` directory. Check to see that you were successful.

Task 3: Download two files that will serve as the basis of your Web work

1. Get into the browser and find your way to the course webpage at:
   `http://danielschlegel.org/wp/teaching/csc212-spring-2020/`
2. From within the *CS1 Web Site Resources* area, download the *style* file for your Web work to the `CS1WorkSite` directory *by carefully proceeding in the following manner*:
   (a) **Important**: Please perform the download in the following way:
      i. *Right click* on the `CS1.css` link.
      ii. Select the `Save Link As ...` option.
      iii. Save the file to your `CS1WorkSite` directory.
   (b) Check, in the *Terminal* window, to be sure that you were successful by listing the files in the `CS1WorkSite` directory and observing.
3. From within the *CS1 Web Site Resources* area, download the main *content* file for your Web work to the `CS1WorkSite` directory *by carefully proceeding in the following manner*:
   (a) **Important**: Please perform the download in the following way:
      i. *Right click* on the `index.html` link.
      ii. Select the `Save Link As ...` option.
      iii. Save the file to your `CS1WorkSite` directory.
   (b) Check, in the *Terminal* window, to be sure that you were successful by listing the files in the `CS1WorkSite` directory and observing.

Task 4: Load the `index.html` file of the `CS1WorkSite` directory into your Web browser

The `index.html` file of the `CS1WorkSite` directory will serve as the main page for your work site. To view it, do one of the following two things:

- Find the `index.html` file icon in your `CS1WorkSite` directory by looking through your file icons, and then double click on the icon.
- Enter the *local address* of the `index.html` file of your `CS1WorkSite` directory into the browser. (Something like: `file:///home/HOME/public_html/CS1WorkSite/index.html` should do.)

Task 5: Edit the content file, `index.html` of the `CS1WorkSite` directory, so that your name replaces the backwards "noname" token

1. Activate the `Emacs` text editor to perform this task.
2. Within the text editor, load the `index.html` file of the `CS1WorkSite` directory. There are various ways to do this. My favorite is to use my hands and type CONTROL-x then CONTROL-f and then interact in the minibuffer.
3. Change the text, replacing "Emanon" with your name.
4. Save the file.
5. Reload the file in the browser and take a look.

Task 6: Edit the style file by changing the background color of the site

1. Load the `CS1.css` file into `Emacs`.
2. Change the background color value in the `CS1.css` file.
3. Save the file.
4. Reload the `index.html` file of the `CS1WorkSite` directory into the browser, and observe.
5. If you are not pleased with the new background color that you have chosen, change it again.

Task 7: Change the style of your site in two other respects

1. Edit the style file by changing the color used for main headers, level `H1` and `H2`, to some color other than blue.
2. Reload the `index.html` file of the `CS1WorkSite` directory into the browser, and observe.
3. Edit the style file by changing the color used for `links` (hyperlinks) to the same color that you chose to use for your main headers.
4. Reload the `index.html` file of the `CS1WorkSite` directory into the browser, and observe.
5. If you don't like the color you chose for these entities, choose again!

Task 8: Make a couple of simple observations

1. Observe (do some clicking) that the links in the "Lab 1 block" of links and in the "Lab 2 block" of links and in the "Assignment 1 block" of links do *not* work.
2. Observe that the links to the various external sites do work.

Task 9: Operationalize your work site links for the Lab 1 source files

1. FYI, this task involves saving the source files from Lab 1 that reside in the IntelliJ `greetings` package of your `CS1` project to the `greetings` directory of your `CS1WorkSite` directory. IntelliJ will do some of the work for us – remember that we haven't created the `greetings` directory (though we could have!). As you work through this, it is important that you get the names and places correct!
2. From within IntelliJ, activate your `HelloWorld.java` program.
3. Ensure you are using the "Light" theme in IntelliJ. If you are not, click *File* then *Settings*, and change the *Theme* option in the *Appearance* panel, under *Appearance & Behavior*.
4. Select `Export to HTML...` from the IntelliJ *File* menu, and then interact with the dialog box that pops up to save `HelloWorld.java` to your `CS1WorkSite` directory. Be sure to option to *Show line numbers* is selected. IntelliJ will create a file, called `HelloWorld.java.html`, inside the appropriate package directory (`CS1WorkSite/greetings`, in this case).
5. From within IntelliJ, activate your `HelloYou.java` program.
6. Select `Export to HTML...` from the IntelliJ *File* menu, and then interact with the dialog box that pops up to save `HelloYou.java` as `HelloYou.html` to your `CS1WorkSite` directory. IntelliJ will create a file, called `HelloWorld.java.html`, inside the `CS1WorkSite/greetings` directory.
7. Back in your terminal, visit your `CS1WorkSite` folder and issue the *list files* command by typing `ls` (that is "elle" "esss") followed by the Enter key. Observe that the `greetings` folder has been created! Navigate inside it to see that two files are there.
8. Reload the web page and check to make sure that both of the links do, indeed, work.

Task 10: Operationalize your work site links for the Lab 2 source files

1. FYI, this task involves saving the source files from Lab 2 that reside in the IntelliJ `npw` and `mmw` packages of your `CS1` project to the `npw` and `mmw` directories that are embedded within your `CS1WorkSite` directory. Remember that IntelliJ will do some of the work for us regarding the creation of, and placement of files in, the `npw` and `mmw` directories. It is important that you get the names and places correct!
2. By analogy with work that you did in the previous task, perform the following save operaton as you did previously for the following files:
   - `BlueDot.java`
   - `Dorothy.java`
   - `BasicsListener.java`
   - `Melody.java`
   - `Target.java`
3. Reload the web page and check to make sure that all of the links do, indeed, work.

Task 11: Operationalize your work site links for the Lab 2 image files

1. Save the picture of the blue dot as an image file.
   (a) Expand IntelliJ so that you can work with it again.
   (b) Run the blue dot painting program.
   (c) Make a screen shot of just the window containing the image of the blue dot (the painter's canvas) by doing the following:
      i. Run the `Screenshot` program, perhaps by way of the *Applications* icon.
      ii. In the window that appears, select the `Grab the current window` option.
      iii. Set the delay to something like 5 seconds.
      iv. Click to `take the screen shot`.
      v. Within a couple of seconds click on the window of interest.
      vi. After the snapshot has been taken, appropriately interact with the system so that the resulting image file (of type `.png`) is saved as `BlueDot.png` into the `npw` directory that is embedded within your `CS1WorkSite` directory (The *other* option of the dialog box is useful for navigating to the desired directory.)
2. Check to see that you were successful.
3. Save the picture of the target as an image file. Specifically, save the picture as `Target.png` within the `npw` directory that is embedded within your `CS1WorkSite` directory. *Work by analogy with what you were asked to do for the blue dot.*
4. Check to see that you were successful.

Task 12: Operationalize your work site links for the Lab 1 standard demo files

1. Focus on getting a demo page up for the "hello world" program. To do this:
   (a) Find your way the course page at:
   `http://danielschlegel.org/wp/teaching/csc212-spring-2020/`
   (b) Simply *left click* on `CS1StandardDemoTemplate.html` link from within the *CS1 Web Site Resources* area.
   (c) Find a way to view the page source. (In the Firefox browser, for example, you might go to the menu bar, open the *Tools* menu, select the `Web Developer` option, and select `Page Source` option from within it.)
   (d) Select the text on the page (all of it), and copy it. You will paste it somewhere else soon enough.

(e) Find your way to the `Emacs` editor. Create a new file called `HelloWorldDemo.html` within the `greetings` folder of your `CS1WorkSite` directory. I like to do this sort of thing with my hands, typing CONTROL-x then CONTROL-f and then interacting with the minibuffer.
(f) Paste the text that you previously copied into the empty buffer.
(g) Change the two place holder items, the question mark and the pound sign, appropriately. The former with `HelloWorld.java` and the latter with code copied from the standard output stream in IntelliJ after you run the `HelloWorld.java` program.
(h) Save the file.
(i) Reload the `index.html` file from your `CS1WorkSite` directory and see if the link to this demo is working properly. If not, carry on trying to get it to work properly!

2. *Working by analogy* with what you just did for the "hello world" program, establish a demo page called `HelloYouDemo.html` within the `greetings` folder of your `CS1WorkSite` directory for the "hello you" program.

Task 13: Operationalize your work site links for the Lab 2 standard demo files

1. Focus on getting a demo page up for the `Dorothy` program. To do this:
   (a) Find your way the course page at:
   `http://danielschlegel.org/wp/teaching/csc212-spring-2020/`
   (b) Simply *left click* on `CS1StandardDemoTemplate.html` link from within the *CS1 Web Site Resources* area.
   (c) Find a way to view the page source.
   (d) Select the text on the page (all of it), and copy it. You will paste it somewhere else soon enough.
   (e) Find your way to the `Emacs` editor. Create a new file called `DorothyDemo.html` within the `mmw` folder of your `CS1WorkSite` directory. I like to do this sort of thing with my hands, typing CONTROL-x then CONTROL-f and then interacting with the minibuffer.
   (f) Paste the text that you previously copied into the empty buffer.
   (g) Change the two place holder items, the question mark and the pound sign, appropriately. The former with `Dorothy.java` and the latter with code copied from the standard output stream in IntelliJ after you run the `Dorothy.java` program.
   (h) Save the file.
   (i) Reload `index.html` file of your `CS1WorkSite` directory and see that the link to this demo is working properly. If not, carry on trying to get it to work properly!
2. *Working by analogy* with what you just did for the `Dorothy` program, establish a demo page within the `mmw` folder of your `CS1WorkSite` directory called `BasicsListenerDemo.html` for the `BasicsListener` program.
3. *Again working by analogy* with what you just did for the `Dorothy` program, establish within the `mmw` folder of your `CS1WorkSite` directory a demo page called `MelodyDemo.html` for the `Melody` program.

Task 14: Incorporate Programming Assignment 1 artifacts into your site

Please incorporate all of the relevant Programming Assignment 1 artifacts into your site. (This task will be a good test of what you should have learned in the previous parts of this lab!) You will need to incorporate source programs, images (which are demos for graphics producing programs), and Standard IO demos into your site as you work through this task, all things that you were taught to do thus far in this lab.

Task 15: Securing your work

In this task, you will adjust the permissions of your website and home folder in order to keep them safe and secure during the semester. You must complete this task in order for Lab 3 to be considered complete by your lab instructor.

1. Test that your website is visible by visiting: `http://cs.oswego.edu/~USERNAME` in a web browser, replacing "USERNAME" with your username.
2. Follow the steps below to allow only your instructors to visit your website for the time being (after the semester you can open it up to everyone!).
   (a) Find your way the course page at:
   `http://danielschlegel.org/wp/teaching/csc212-spring-2020/`
   (b) From within the *Web Site Resources* area, download the `htaccess.txt` file and save it to your `CS1WorkSite` directory.
   (c) Open a terminal and navigate to your `CS1WorkSite` directory.
   (d) Run the command: `mv htaccess.txt .htaccess`
   This will rename the `.htaccess` file, which enforces some authentication on the directory.
   (e) Now visit your website in the browser as you did a minute ago. You should now be faced with a login window! Your username and password won't work, but don't worry, ours will!
   (f) You can continue to see your website locally by just opening the `index.html` file in Firefox. Test this to make sure it still works and that you can see your page.
3. Restrict access to your important files. For any folder or file in your directory that you would like to keep others out of, we will change the permissions. We'll do it on your `IdeaProjects` folder, but you should work by analogy for any other folder you want to keep prying eyes away from.
   (a) Open a terminal and get to your home directory.
   (b) Type: `chmod 700 IdeaProjects`

Task 16: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

7 Presentation: Command Line OS, Text Editing, The Web

This material is presented in real time during the course lectures.

8 Lab 4: Expressions and Shapes World Problem Solving

E. W. Dijkstra on ABSTRACTION

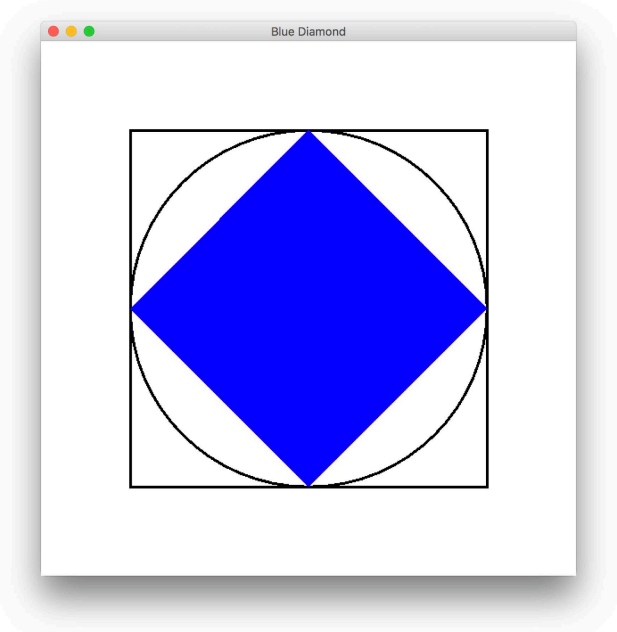
Being abstract is something profoundly different from being vague. The purpose of abstraction is not to be vague, but to create a new semantic level in which one can be absolutely precise.

Overview

For this lab you will be asked to write two programs, each a little bit at a time. The first program involves *arithmetic expressions*. The second program involves *shapes* from the NPW. You will also be asked to post these programs, as well as output generated by these programs, to your work site.

Blue Diamond

The blue diamond depicted here was the inspiration for the `ShapesThing` program that is featured in the second half of this lab. Keeping it in mind may make that part of the lab a bit more meaningful to you. Moreover, the loose geometric connotations that it conjures in the mind should prime you to better think thoughts with respect to elements of the `ExpressionsThing` program that is featured in the first part of the lab.



Why do it?

As you work through this lab you will:

1. Introduce *variables* and *bind* them to *values*.
2. Perform computations involving *fully parenthesized* arithmetic expressions.
3. Create shapes from the NPW, both *directly* with constructors and *indirectly* via *inscribing/circumscribing* functionality.
4. Perform computations involving *shapes* in the NPW.

Some things you will need to know ...

For this lab you need to know three specific things: (1) what it means for an expression to be *fully parenthesized*, (2) how to play a game called *Crypto*, and (3) a couple of specific concepts pertaining to shapes and the corresponding bits of shape generating *functionality* found in the NPW.

1. A **fully parenthesized expression** is an expression for which there is *exactly* one set of parentheses corresponding to each operator. For example: `(5 + 3)`, `( ( 9 - 4 ) * 3 )`, `5`, and `( ( ( 3 + 3 ) + 3 ) + 3 )` are all fully parenthesized arithmetic expressions. These are not: `( ( 5 + 5 ) )`, `( 3 * 3 * 3)`, and `(111)`.
2. The **Crypto Problem** is just this: Given N *source numbers* and one *goal number*, all integers within a prescribed range, construct a *fully parenthesized* arithmetic expression that evaluates to the goal number which uses all of the source numbers and zero or more occurrences of each of the four basic arithmetic operators. For example: Make `5` (the goal) from `8 4 5 2` (the sources). Here is one possible solution: `( 5 + ( 8 - ( 4 * 2 ) ) )`.
3. The **inscribing circle** of a given square is the circle that intersects the square at the midpoint of each side of the square. The **inscribing square** of a given circle is the square that intersects the circle at each of its four corners. The **circumscribing circle** of a given square is the circle that intersects the square at each of its four corners. The **circumscribing square** of a given circle is the square that intersects the circle at the midpoint of each of its four sides. You may find it helpful to look over the specifications for the *simple shapes* functionality of the NPW (see Appendix 1) that pertain to these definitions.

Task 1: Get ready to do some work

1. Log on to a sanctioned machine.
2. Open *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Start creating an `ExpressionsThing` program

1. Create a package...
   (a) Right click on the `src` folder and create a new `Package`.
   (b) In the window that appears, call your package `expressions` and click `OK`.
2. Create a source program...
   (a) Right click on the `expressions` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...

i. Type `ExpressionsThing` into the *Name* field.
ii. Select `Class` if it isn't already.
iii. Press the Enter key on the keyboard.

3. Write a multiline comment at the start of the file containing something reasonable; something to suggest the fact that this program affords opportunities to explore the construction of arithmetic expressions in the context of some very simple problem solving.

Task 3: Three related expressions

1. Create an empty `main` method. Look to previous lab source files for what the `main` method declaration should look like.
2. To the `main` method, add the following code which features three expressions "intended" to compute the *perimeter* of a circle of radius `5` (using `3.14` as an approximation to `PI`).

```
double one = 3.14 * 5 + 5;
System.out.println("one = " + one);
double two = 3.14 * ( 5 + 5 );
System.out.println("two = " + two);
double three = ( 3.14 * ( 5 + 5 ) );
System.out.println("three = " + three);
```

3. Run your program. Which expression is incorrect, in that it doesn't produce the expected result? (Write it down.)

4. Which expression is fully parenthesized? (Write it down)

Task 4: Translating fully parenthesized arithmetic expressions from English

1. FYI, items in this task will ask you to add pairs of statements to the `ExpressionsThing` program. The first statement of each pair is supposed to introduce a variable and bind it to a value expressed as a straightforward translation of an English phrase representing a numeric computation. The second statement of the pair is merely supposed to display the value of the expression, reasonably labelled.
2. On one line, introduce a variable called `four` of type `int`, and bind it to a fully parenthesized expression that computes the value of "five times six".
3. On the next line, print the value, labeled. That is, type: `System.out.println("four = " + four);`
4. Run your program.
5. On one line, introduce a variable called `five` of type `double`, and bind it to a fully parenthesized expression that computes the value of "one-half of fifty-five".
6. On the next line, print the value, labeled. That is, type: `System.out.println("five = " + five);`
7. Run your program. **Please be sure to check your answer! Precisely, what is one-half of fifty-five?**
8. On one line, introduce a variable called `six` of type `double`, and bind it to a fully parenthesized expression that computes the value of "one-third of sixty-five".
9. On the next line, print the value, labeled. That is, type: `System.out.println("six = " + six);`
10. Run your program.
11. On one line, making good use of previously bound variables, introduce a variable called `seven` of type `double`, and bind it to a fully parenthesized expression that computes the value of "one-half of fifty-five plus one-third of sixty-five".

12. On the next line, print the value, labeled. That is, type: `System.out.println("seven = " + seven);`
13. Run your program.

Task 5: Computations based on simple geometric/algebraic conceptions

1. FYI, items in this task will ask you to add more pairs of statements to the `ExpressionsThing` program. The first statement of each pair is supposed to introduce a variable and bind it to a solution to simple geometric or algebraic problem. The second statement of the pair is merely supposed to display the value of the expression, reasonably labelled.
2. On one line, introduce a variable called `eight` of type `double`, and bind it to a fully parenthesized expression that computes the value of the area of a circle of radius `11.3`, using `3.14` for `PI`. (For this item, please use `( PI * ( R * R ) )` as the model for computing the area of a circle of radius R).
3. On the next line, print the value, labeled. That is, type: `System.out.println("eight = " + eight);`
4. Run your program.
5. On one line, introduce a variable called `nine` of type `double`, and bind it to a fully parenthesized expression that computes the value of the area of a square of side `27.7`. (For this item, please use `( S * S )` as the model for computing the area of a square of side length S).
6. On the next line, print the value, labeled. That is, type: `System.out.println("nine = " + nine);`
7. Run your program.
8. On one line, making good use of previously bound variables, introduce a variable called `ten` of type `double`, and bind it to a fully parenthesized expression that computes the average value of the area of a circle of radius `11.3` and the area of a square of side `27.7`.
9. On the next line, print the value, labeled. That is, type: `System.out.println("ten = " + ten);`
10. Run your program.
11. On one line, introduce a variable called `eleven` of type `double`, and bind it to a fully parenthesized expression that computes `17` percent of `243.5`.
12. On the next line, print the value, labeled. That is, type: `System.out.println("eleven = " + eleven);`
13. Run your program.

Task 6: Simple computations to solve Crypto problems

1. FYI, items in this task will ask you to add yet more pairs of statements to the `ExpressionsThing` program. The first statement of each pair is supposed to introduce a variable and bind it to a solution to a *Crypto* problem. The second statement of the pair is merely supposed to display the value of the expression, reasonably labelled. **Please don't forget that a solution to a Crypto problem is a *fully parenthesized* arithmetic expression!**
2. On one line, introduce a variable called `twelve` of type `int`, and bind it to a fully parenthesized expression that uses the numbers `3` and `3` as *sources* and that evaluates to the number `1` as *goal*.
3. On the next line, print the value, labeled. That is, type: `System.out.println("twelve = " + twelve);`
4. Run your program.
5. On one line, introduce a variable called `thirteen` of type `int`, and bind it to a fully parenthesized expression that uses the numbers `4` and `7` and `2` as *sources* and that evaluates to the number `1` as *goal*.
6. On the next line, print the value, labeled. That is, type: `System.out.println("thirteen = " + thirteen);`
7. Run your program.
8. On one line, introduce a variable called `fourteen` of type `int`, and bind it to a fully parenthesized expression that uses the numbers `1` and `3` and `7` and `9` as *sources* and that evaluates to the number `4` as *goal*.
9. On the next line, print the value, labeled. That is, type: `System.out.println("fourteen = " + fourteen);`
10. Run your program.
11. On one line, introduce a variable called `fifteen` of type `int`, and bind it to a fully parenthesized expression that uses the numbers `2` and `2` and `4` and `6` and `8` as *sources* and that evaluates to the number `5` as *goal*.

12. On the next line, print the value, labeled. That is, type: `System.out.println("fifteen = " + fifteen);`
13. Run your program.

Task 7: Start creating a `ShapesThing` program

1. Create a package...
   (a) Right click on the `src` folder and create a new `Package`.
   (b) In the window that appears, call your package `shapes` and click `OK`.
2. Create a source program ...
   (a) Right click on the `shapes` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `ShapesThing` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
3. Write a multiline comment at the start of the file containing something reasonable, something to suggest the fact that this program affords opportunities to explore the computational solution to simple geometrical problems by means of the construction and use of basic shapes.
4. Create an empty `main` method. Look to previous lab source files for what the `main` method declaration should look like.

Task 8: Computations on a square

1. Add a line of code that introduces a variable called `square` of type `SSquare`, and bind it to a new square of side `400`.
2. Add the following line of code to your program, and then run your program:
   `System.out.println("square = " + square.toString());`
3. Add the following line of code to your program, and then run your program:
   `System.out.println("area of square = " + square.area());`
4. Using the previous item as a model, add a line of code to compute and print the *perimeter* of the square. Then run your program. (No use of the four basic arithmetic operators allowed! Where would you look in this lab manual which might help?)
5. Using the previous two items as models, add a line of code to compute and print the *diagonal* of the square. Then run your program. (No use of the four basic arithmetic operators allowed! Where would you look in this lab manual which might help?)

Task 9: Computations on a circle

1. Add the following code to establish a circle called `disk` of type `SCircle` and bind it to the *inscribing circle* of the variable to which `square` is bound.
   `SCircle disk = square.inscribingCircle();`
2. Add the following line of code to your program, and then run your program:
   `System.out.println("disk = " + disk.toString());`
3. Working by analogy with the code to compute and display the area of the `square`, compute and display the area of the `disk`. Run the program.
4. Working by analogy with the code to compute and display the perimeter of the `square`, compute and display the perimeter of the `disk`. Run the program.

Task 10: Computations on a another square

1. Add a line of code to establish a square called `diamond` of type `SSquare` and bind it to the *inscribing square* of the `disk`
2. Add the following line of code to your program, and then run your program:
   `System.out.println("diamond = " + diamond.toString());`
3. Write code to compute and display the area of the `diamond`. Run the program.

Task 11: Post your code and associated *demos* to your work site

Create a space on your work site to represent the work that you have done for this lab. To do this, please open the `index.html` file of your `CS1WorkSite` directory in the `Emacs` text editor, and copy the clump of code associated with *Lab 1* to a point just after the clump of code associated with *Lab 3*. Then appropriately edit this code. (Working in this fashion, you are more likely to faithfully adhere to the proper format for your `CS1` work site than if you just type from scratch.) Broken down a bit, here is what you will want to do:

1. Edit the `index.html` file (in the manner suggested above) so that it properly represents Lab 4. You will want to be sure to arrange for this clump of code (the clump associated with Lab 4) to reference the four relevant files for this lab: appropriate versions of the source and demo for `ExpressionsThing` and for `ShapesThing`.
2. Use IntelliJ to generate the `.html` version of the `ExpressionsThing.java`. If you've done it correctly, it will place the file inside a folder called `expressions` inside your `CS1WorkSite` folder. Check to make sure the link works on your work site!
3. Use IntelliJ to generate the `.html` version of the `ShapesThing.java`. If you've done it correctly, it will place the file inside a folder called `shapes` inside your `CS1WorkSite` folder. Check to make sure the link works on your work site!
4. Carefully, working in the manner prescribed in your previous lab, create a Standard IO demo file for the `ExpressionsThing` program, and place it in the `expressions` folder of your work site work area. Check to make sure the link works on your work site!
5. Carefully, working in the manner prescribed in your previous lab, create a Standard IO demo file for the `ShapesThing` program, and place it in the `shapes` folder of your work site work area. Check to make sure the link works on your work site!

Task 12: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

9 Presentation: Basic Data Types, Problem Solving Strategies

This material is presented in real time during the course lectures.

10 Lab 5: An Interpreter Featuring *Loop Forever* and Selection

Albert Einstein on TEACHING

Example isn't another way to teach. It is the only way to teach.

Overview

For this lab you will be asked to write a sequence of three *interpreters*. An **interpreter** is a program that *recognizes* and *responds to* commands. The interpreters will display dots of various colors in a window. Input will be obtained through one kind of *dialog box*. Output associated with a `HELP` command, as well as *error messages*, will be displayed through another kind of *dialog box*.

Why do it?

In this lab you will gain experience in doing the following things:

1. Writing an *interpreter*, complete with a `HELP` command and an *error reporting mechanism*.
2. Iterating by means of a *loop forever* construct.
3. Making use of a `break` statement to escape from a loop forever construct.
4. Coding a *multiway conditional* construct.
5. Working from a previous program to create a new program.
6. Creating random colors!

Task 1: Get ready to do some work

1. Log on to a sanctioned machine.
2. Open *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Create an `Interpreter1` program

1. Create a package...
   (a) Right click on the `src` folder and create a new `Package`.
   (b) In the window that appears, call your package `interpreters` and click `OK`.
2. Create a source program...
   (a) Right click on the `interpreters` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...

i. Type `Interpreter1` into the *Name* field.
ii. Select `Class` if it isn't already.
iii. Press the Enter key on the keyboard.

3. Edit the template so that it looks like the following:

`Interpreter1` Program

```
/*
 * This interpreter is intended to paint different colored dots in a window.
 *
 * The commands that the interpreter can recognize and respond to are:
 *  - BLUE: paint a blue dot
 *  - RED: paint a red dot
 *  - HELP: show a list of the commands in a dialog message box
 *  - EXIT: terminate the program
 */

package interpreters;

import java.awt.Color;
import javax.swing.JOptionPane;
import javax.swing.SwingUtilities;
import painter.SPainter;
import shapes.SCircle;

public class Interpreter1 {

    private void interpreter() {

        // CREATE OBJECTS TO THINK WITH
        SPainter miro = new SPainter("Dot Thing",400,400);
        miro.setScreenLocation(0,0);
        SCircle dot = new SCircle(180);

        // REPEATEDLY TAKE A COMMAND FROM AN INPUT DIALOG BOX AND INTERPRET IT
        while ( true ) {
            String command = JOptionPane.showInputDialog(null,"Command?");
            if ( command == null ) { command = "exit"; } // user clicked on Cancel
            if ( command.equalsIgnoreCase("blue") ) {
                miro.setColor(Color.BLUE);
                miro.paint(dot);
            } else if ( command.equalsIgnoreCase("red") ) {
                miro.setColor(Color.RED);
                miro.paint(dot);
            } else if ( command.equalsIgnoreCase("help") ) {
                JOptionPane.showMessageDialog(null,"Valid commands are: "
                        + "RED | BLUE | HELP | EXIT ");
            } else if ( command.equalsIgnoreCase("exit") ) {
                miro.end();
                System.out.println("Thank you for viewing the dots ...");
                break;
            } else {
                JOptionPane.showMessageDialog(null, "Unrecognizable command: "
```

```
                        + command.toUpperCase());
            }
        }

    }

    // INFRASTRUCTURE FOR SOME SIMPLE PAINTING

    public Interpreter1() {
        interpreter();
    }

    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
                new Interpreter1();
            }
        });
    }

}
```

---

4. Read the program, doing your best to understand what it does and how it does what it does.
5. Run the program, providing it with the following commands (one at a time): `RED BLUE GREEN RED BLUE HELP RED BLUE EXIT`

Task 3: Create an `Interpreter2` program

1. Create a source program ...
   (a) Right click on the `interpreters` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `Interpreter2` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
2. Completely replace the text of this `Interpreter2` program with the text of the `Interpreter1` program.
3. Appropriately change the token `Interpreter1` to the token `Interpreter2` throughout the program. (Note that there are three instances to be changed!)
4. Run the `Interpreter2` program, just to make sure that it is working like the `Interpreter1` program.
5. Now, modify the program so that it can interpret two more commands: `GREEN` and `YELLOW`. In doing so, be sure to:
   (a) Edit the opening comment of the program appropriately
   (b) Add two cases to the multiway conditional statement
   (c) Add the two commands to the `HELP` mechanism.
6. Run the program, being sure to try out the new commands. Give the revised `HELP` command a look, as well.

Task 4: Create an `Interpreter3` program

1. Create a source program ...
   (a) Right click on the `interpreters` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `Interpreter3` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
2. Completely replace the text of this `Interpreter3` program with the text of the `Interpreter2` program. by doing the following:
3. Appropriately change the token `Interpreter2` to the token `Interpreter3` throughout the program. (Note that there are three instances to be changed!)
4. Run the `Interpreter3` program, just to make sure that it is working like the `Interpreter2` program.
5. Now, modify the program so that it can interpret one more command: `RANDOM`. In doing so:
   (a) Edit the opening comment of the program appropriately
   (b) Implement the new command by doing the following:
      i. Add the following case to the multiway conditional statement:

```
} else if ( command.equalsIgnoreCase("random") ) {
   miro.setColor(randomColor());
   miro.paint(dot);
```

      ii. Notice that `randomColor()` is red. IntelliJ likes to use red text and red underlines to indicate problems. Click on the red text.
      iii. Use the light bulb which appears (after about a second) to create a method *stub* for the `randomColor()` method. A **stub** is simply a method with essentially no body. When you click the light bulb one of the options should be something like *Create method 'randomColor' in 'Interpreter3'*. Use that one.
      iv. Edit the `randomColor()` method so that it appears as follows:

```
private static Color randomColor() {
    int rv = (int)(Math.random()*256);
    int gv = (int)(Math.random()*256);
    int bv = (int)(Math.random()*256);
    return new Color(rv,gv,bv);
}
```

   (c) Add the new command to the `HELP` mechanism.
6. Run the program, being sure to try out the new command. Give the revised `HELP` command a look, as well.

Task 5: Post your code and selected *demos* to your work site

Create a space on your work site to represent the work that you have done for this lab. To do this, please open the `index.html` file of your `CS1WorkSite` directory in the `Emacs` text editor, and copy the clump of code associated with *Lab 4* to a point just after the *Lab 4* clump of code. Then appropriately edit this code. (Working in this fashion, you are more likely to faithfully adhere to the proper format for your `CS1` work site than if you just type from scratch.) Broken down a bit, here is what you will want to do:

1. Edit the `index.html` file (in the manner suggested above) so that it properly represents Lab 5. You will want to be sure to arrange for this clump of code (the clump associated with Lab 5) to reference at least seven files: the `.html` version of the `Interpreter1.java` program, the `.html` version of the `Interpreter2.java` program, and the `.html` version of the `Interpreter3.java` program, and at least four separate snapshots which, minimally, capture a colored dot in a canvas, an input dialog box, an error message dialog box, and a help menu dialog box. Perhaps it would be most interesting to generate these with the third version of the program. Some context (regular text) for the links (hypertext) might be a very good idea!
2. Place the `.html` version of the `Interpreter1.java` program in the `interpreters` folder. Check to make sure the link works on your work site!
3. Place the `.html` version of the `Interpreter2.java` program in the `interpreters` folder. Check to make sure the link works on your work site!
4. Place the `.html` version of the `Interpreter3.java` program in the `interpreters` folder. Check to make sure the link works on your work site!
5. Carefully, working by analogy with the posting of the blue dot (refer back to Lab 3 if you need to), add to your work site a randomly colored dot canvas image that was generated by your `Interpreter3` program.
6. Add to your site a reference to an image of an input dialog box.
7. Add to your site a reference to an image of a message dialog box that displays a *HELP* message.
8. Add to your site a reference to an image of a message dialog box that displays an *error* message.
9. As always, check to make sure the links are working as desired.

Task 6: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

11 Presentation: Selection (`if`) and Repetition (`while`)

This material is presented in real time during the course lectures.

12 Lab 6: Functions and Commands

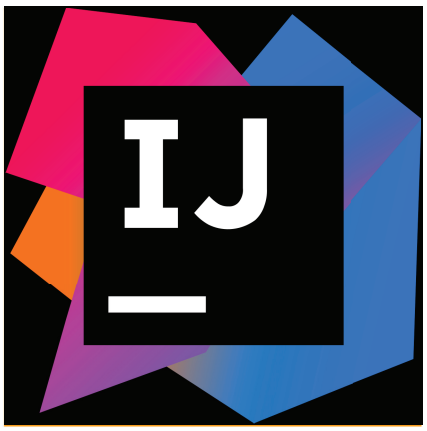
Abelson and Sussman on PROCEDURAL PROGRAMMING

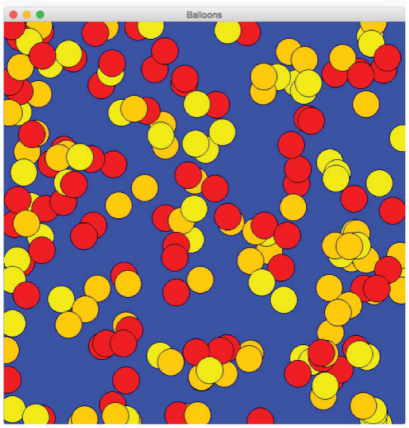
The computer revolution is a revolution in the way we think and in the way we express what we think. The essence of this change is the emergence of what might best be called procedural epistemology - the study of the structure of knowledge from an imperative point of view, as opposed to the more declarative point of view taken by classical mathematical subjects.

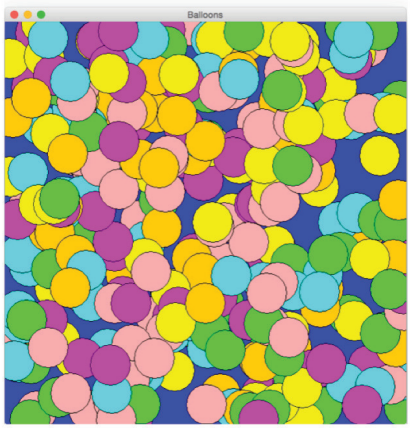
Simon Peyton Jones on FUNCTIONAL PROGRAMMING

When the limestone of imperative programming has worn away, the granite of functional programming will be revealed underneath!

Pictorial preview of things/thinks to come







Overview

For this lab you will be asked to write one program that features *functions* and one program that features *commands*. A **function** is a method that is characterized by the return of a value. Any actions performed during execution of the method are performed in the service of computing the value to be returned. A **command** is a method that is characterized by performing some action. Any values that are computed during execution of the method are computed in the service of performing the action. You will be asked to mindfully engage in the process of *stepwise refinement* as you prepare the first two programs for execution. Finally, you will be asked to perform a simple program alteration.

Why do it?

In this lab you will gain experience in doing the following things:

1. Defining and using *functions*.
2. Defining and using *commands*.
3. Program construction by means of *stepwise refinement*.
4. Program modification.
5. Iteration using the `while` statement.
6. Conditional execution using the `if` statement.

Task 1: Get ready to do some work

1. Log on to a sanctioned machine.
2. Open *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Create a `SurfaceAreaOfCube` program

1. Create a package...
   (a) Right click on the `src` folder and create a new `Package`.
   (b) In the window that appears, call your package `mathematics` and click `OK`.
2. Create a source program...
   (a) Right click on the `mathematics` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `SurfaceAreaOfCube` into the *Name* field.
      ii. Select `Class` if it isn't already.
      iii. Press the Enter key on the keyboard.
3. Edit the template so that it looks like the accompanying program. Do this in the following manner:
   (a) Write the multiline comment at the start of the file appropriately.
   (b) Create an empty `main` method, then edit it appropriately.
   (c) Making good use of the *red text* and *light bulbs*, let IntelliJ help you to create both *stubs*: the one for the `edgeLength` method and the one for the `surfaceArea` method.
   (d) Edit the `edgeLength` method. Notice that `Scanner` is colored red. Click on it and do as IntelliJ suggests to import the `Scanner` class.
   (e) Edit the `surfaceArea` method. Let IntelliJ import the `SSquare` class as you do.

Program: `SurfaceAreaOfCube`

```
/*
 * Program that features two functions to compute the surface area of a cube.
 * - The edge length will be read from the standard input stream.
 * - The surface area will be printed to the standard output stream.
 * - A face of the cube will be modeled as a simple square.
 */

package mathematics;

import java.util.Scanner;
import shapes.SSquare;

public class SurfaceAreaOfCube {

    public static void main(String[] args) {
        double edgeLength = edgeLength();
        double surfaceArea = surfaceArea(edgeLength);
        System.out.println("surface area = " + surfaceArea);
    }

    private static double edgeLength() {
        System.out.print("Please enter the edge length of the cube: ");
        Scanner scanner = new Scanner(System.in);
        double edgeLength = scanner.nextDouble();
        return edgeLength;
    }

    private static double surfaceArea(double edgeLength) {
        SSquare face = new SSquare(edgeLength);
        int nrOfFaces = 6;
        double surfaceArea = face.area() * nrOfFaces;
        return surfaceArea;
    }

}
```

4. Run the program to compute and print the surface area of a cube of edge length `7.5` units.
5. Run the program to compute and print the surface area of a cube of edge length `12.95` units.

Task 3: Thinking on stepwise refinement

To be productive in what you do, you generally want to become one with your tools. That is, you want to learn to make use of your tools in a natural, effective, efficient manner. One way that you can make good use of *IntelliJ* is to, more often than not, write your programs with the *principle of stepwise refinement* in mind. Just *think on these things* before continuing on with the next task in this lab:

1. According to the **principle of stepwise refinement**, you craft a solution to a problem at a level of abstraction which affords *naturalness of expression* with respect to the problem domain and the application of *powerful cognitive operators*. If the solution incorporates *abstractions*, which is normally the case, you then *refine* the abstractions by rendering them real in some sense. The term *stepwise* refers to the fact that refinement of an abstraction at one level may introduce further abstractions at the next level.
2. In the `SurfaceAreaOfCube` program, a solution to the problem was coded in the `main` method which introduced two *abstractions*, the `edgeLength` method and the `surfaceArea` method. Each of these methods was, in turn, *refined* by defining the methods.
3. Note that the process of stepwise refinement was facilitated by the mechanism in IntelliJ for automatically generating *stubs* for the methods by means of handy *light bulbs* which appear from time to time with suggestions for how you might like to proceed. Making *appropriate*, *judicious* use of these suggestions is one way that you work in a natural, efficient manner with IntelliJ.

Task 4: Create a `Balloons` program

Establish a source program template ...

1. Right click on the `npw` package and create a new `Java Class`.
2. On the *New Java Class* form that appears ...
   (a) Type `Balloons` into the *Name* field.
   (b) Select `Class` if it isn't already.
   (c) Press the Enter key on the keyboard.
3. Edit the template so that it looks like the accompanying program. *Be sure to work with IntelliJ in order to accomplish this task in a manner that is consistent with the principle of stepwise refinement!*

Program: `Balloons`

```
/*
 * Program that paints 100 red, yellow and orange balloons in a blue sky.
 * It will feature commands.
 */

package npw;

import java.awt.Color;
import java.util.Random;
import javax.swing.SwingUtilities;
import painter.SPainter;
import shapes.SCircle;
import shapes.SSquare;

public class Balloons {

    // REQUIRED INFRASTRUCTURE

    public Balloons() {
        paintTheImage();
    }

    public static void main(String[] args) {
        SwingUtilities.invokeLater(new Runnable() {
            public void run() {
```

```
                new Balloons();
            }
        });
    }

    // THE PAINTER DOING ITS THING

    private void paintTheImage() {
        SPainter painter = new SPainter("Balloons", 600, 600);
        paintSky(painter); // ask IntelliJ to generate the stub
        int nrOfBalloons = 100;
        paintBalloons(painter,nrOfBalloons);  // ask IntelliJ to generate the stub
    }

    private void paintSky(SPainter painter) {
        painter.setColor(Color.BLUE);
        SSquare sky = new SSquare(2000);
        painter.paint(sky);
    }

    private void paintBalloons(SPainter painter, int nrOfBalloons) {
        int i = 1;
        while ( i <= nrOfBalloons ) {
            paintOneBalloon(painter);  // ask IntelliJ to generate the stub
            i = i + 1;
        }
    }

    private void paintOneBalloon(SPainter painter) {
        Random rgen = new Random();
        int rn = rgen.nextInt(3);
        if ( rn == 0 ) {
            painter.setColor(Color.RED);
        } else if ( rn == 1 ) {
            painter.setColor(Color.ORANGE);
        } else {
            painter.setColor(Color.YELLOW);
        }
        painter.move();
        int balloonRadius = 20;
        SCircle balloon = new SCircle(balloonRadius);
        painter.paint(balloon);
        painter.setColor(Color.BLACK);
        painter.draw(balloon);
    }

}
```

---

4. Run the program.

Task 5: Create a `AlternateBalloons` program

Establish a source program template ...

1. Right click on the `npw` package and create a new `Java Class`.
2. On the *New Java Class* form that appears ...
   (a) Type `AlternateBalloons` into the *Name* field.
   (b) Select `Class` if it isn't already.
   (c) Press the Enter key on the keyboard.
3. Replace all of the code in the `AlternateBalloons` program with all of the code in the `Balloons` program.
4. Then, edit the `AlternateBalloons` program in such a way that 300 balloons, each of radius 30, of 6 different "nameless" colors, will randomly populate the sky. By *nameless* I don't meant that you can't imagine a name for the color, but merely that you must use a color constructor to obtain the color since there is not predefined name for it in Java. (Please don't forget to modify the leading comment.)
5. Run the program.

Task 6: Post your code and selected *demos* to your work site

Work by analogy with the way that you have posted artifacts to your site for previous labs. In brief, you will need to:

1. Edit the `index.html` file of your `CS1WorkSite` directory.
2. You will need to create two files for the `SurfaceAreaOfCube` program, one for the source program, and one for the Standard IO demo.
3. You will need to create two files for the `Balloons` program, one for the source program, and one for the image.
4. You will need to create two files for the `AlternateBalloons` program, one for the source program, and one for the image.

Task 7: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

13 Presentation: Application Architectures

This material is presented in real time during the course lectures.

14 Lab 7: String Thing

Kernighan and Pike on "RUBBER DUCKING"

Another effective [debugging] technique is to explain your code to someone else. This will often cause you to explain the bug to yourself. Sometimes it takes no more than a few sentences, followed by an embarrassed "Never mind, I see what's wrong. Sorry to bother you." This works remarkably well; you can even use non-programmers as listeners. One university computer center kept a teddy bear near the help desk. Students with mysterious bugs were required to explain them to the bear before they could speak to a human counselor.

Overview

This lab features two programs. The first program, `StringOps`, which you will merely type in and run, provides you with an opportunity to get acquainted with some basic character string processing functionality. The second program, `StringThing`, provides you with an opportunity to write some character string processing code.

Why do it?

As you work through this lab you will:

1. Get acquainted with some basic character string processing functionality.
2. Solve some simple problems in the context of character string programming.
3. Perform abstraction by writing methods, by introducing names (parameters) to stand for instances of data items.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Study (read/create/run/reflect upon) the accompanying `StringOps` program

1. Carefully read through the accompanying `StringOps` program.
2. Within a package called `stringthing`, establish a Java Class called `StringOps`. Then, enter the accompanying program, just as it is presented here.

The `StringOps` Program

```
/*
 * Program to illustrate some basic character string processing functionality.
 */

package stringthing;

public class StringOps {

    public static void main(String[] args) {

        // ESTABLISH SOME STRINGS
        String date = "Wednesday, October 18, 1995";
        String time = "8 AM";
        String lab = "String Thing";

        // COMPUTE THE LENGTHS OF THE STRINGS
        int dateLength = date.length();
        int timeLength = time.length();
        int labLength = lab.length();
        System.out.println("\ndateLength = " + dateLength);
        System.out.println("timeLength = " + timeLength);
        System.out.println("labLength = " + labLength);

        // COMPUTE SOME POSITIONS
        int p1 = date.indexOf(",");
        int p2 = time.indexOf(" ");
        int p3 = lab.indexOf("ing");
        System.out.println("\np1 = " + p1);
        System.out.println("p2 = " + p2);
        System.out.println("p3 = " + p3);

        // COMPUTE SOME 2 ARGUMENT SUBSTRING VALUES
        System.out.println("\ndate.substring(0,9) = " + date.substring(0,9));
        System.out.println("time.substring(2,4) = " + time.substring(2,4));
        System.out.println("lab.substring(7,8) = " + lab.substring(7,8));

        // COMPUTE SOME 1 ARGUMENT SUBSTRING VALUES
        System.out.println("\ndate.substring(11) = " + date.substring(11));
        System.out.println("time.substring(2) = " + time.substring(2));
        System.out.println("lab.substring(7) = " + lab.substring(7));

        // CREATE A STRING
        String line = date + " | " + time + " | " + lab;
        System.out.println("\nline = " + line);

    }

}
```

3. Run the program.
4. Change the date in the first executable statement to today's date, and the time in the second executable statement to the current time.
5. Again, run the program.
6. Reflect upon the program and its output. As you do, take a few minutes to infer some of the string processing functionality and write down answers to the following questions. **Thinking about the answers to these questions is one of the most important parts of this lab — try to work independently on this!**
   (a) What does the `length` function do? Simply write a brief description of the `length` function.

   (b) What does the `indexOf` function do? Simply write a brief description of the `indexOf` function.

   (c) What does the `substring` function which takes *two* parameters do? Simply write a brief description of the `substring` function which takes *two* parameters.

   (d) What does the `substring` function which takes *one* parameter do? Simply write a brief description of the `substring` function which takes *one* parameters.

   (e) What does the "plus operator", aka the *concatenation* operator do? Simply write a brief description of this workhorse string processing operator.

Task 3: Prepare to refine (complete) the accompanying `StringThing` program

1. Carefully read through the accompanying `StringThing` program.
2. Within your package called `stringthing`, establish a Java Class called `StringThing`. Then, enter the program just as it is presented here.

The `StringThing` Program

```
/*
 * This program will do a bit of character string processing.
 */

package stringthing;

public class StringThing {

    public static void main(String[] args) {
        // POINT A: CREATE A PRINT SOME STRINGS THAT REPRESENT NAMES
        // String singer = "Holiday, Billie";
        // String sculptor = "Claudel, Camille";

        // POINT B: COMPUTE AND PRINT THE LENGTHS OF THE STRINGS, WITHOUT LABELS

        // POINT C: COMPUTE AND PRINT THE LOCATION OF THE COMMA WITHIN EACH STRING, NO LABELS

        // POINT D: COMPUTE AND PRINT THE FIVE FIRST NAMES, WITH NO LABELS

        // POINT E: COMPUTE AND PRINT THE FIVE LAST NAMES, WITH NO LABELS

        // POINT F: COMPUTE AND PRINT THE FIRST NAMES, AGAIN
//        System.out.println("\nFirst names, once again ...");
//        System.out.println(firstName(singer));
//        System.out.println(firstName(sculptor));
//        System.out.println(firstName(painter));
//        System.out.println(firstName(dancer));
//        System.out.println(firstName(self));

        // POINT G: COMPUTE AND PRINT THE LAST NAMES, AGAIN
//        System.out.println("\nLast names, once again ...");
//        System.out.println(lastName(singer));
//        System.out.println(lastName(sculptor));
//        System.out.println(lastName(painter));
//        System.out.println(lastName(dancer));
//        System.out.println(lastName(self));

        // POINT H: COMPUTE AND PRINT THE FULL NAMES, NATURAL STYLE
//        System.out.println("\nFull names, natural style ...");
//        System.out.println(fullName(singer));
//        System.out.println(fullName(sculptor));
//        System.out.println(fullName(painter));
//        System.out.println(fullName(dancer));
//        System.out.println(fullName(self));
```

```
    }

}
```

Task 4: `Point A` programming

1. Toggle the comments on the two lines *following* the `Point A` comment.
2. Add a line of code which introduces a variable called `painter` and binds it to `"Picasso, Pablo"` - the directory style string representation of Pablo Picasso.
3. Add a line of code which introduces a variable called `dancer` and binds it to `"Zotto, Osvaldo"` - the directory style string representation of Osvaldo Zotto.
4. Add a line of code which introduces a variable called `self` and binds it to your *directory style* name.
5. Add the following line of code: `System.out.println("\nNames ...");`
6. Add five lines of code, one to print each of the five name strings (unlabelled), being sure to do so by referencing the name strings through the *variables* to which they are bound.
7. Run the program.

Task 5: `Point B` programming

For this task you will want to use the `length` method of the `String` class. If you should need a hint for how to do this, simply look at the part of the `StringOps` program that computes string lengths.

1. Introduce a variable called `singerLength` and bind it to the length of the name string of the singer. Be sure to arrange for the computer to compute the length. (Be sure not to do it yourself by counting!)
2. Introduce a variable called `sculptorLength` and bind it to the length of the name string of the sculptor. Be sure to arrange for the computer to compute the length. (Be sure not to do it yourself by counting!)
3. Introduce a variable called `painterLength` and bind it to the length of the name string of the painter. Be sure to arrange for the computer to compute the length. (Be sure not to do it yourself by counting!)
4. Introduce a variable called `dancerLength` and bind it to the length of the name string of the dancer. Be sure to arrange for the computer to compute the length. (Be sure not to do it yourself by counting!)
5. Introduce a variable called `selfLength` and bind it to the length of your name string. Be sure to arrange for the computer to compute the length. (Be sure not to do it yourself by counting!)
6. Add the following line of code: `System.out.println("\nName lengths ...");`
7. Add five lines of code, one to print the length of each of the five name string lengths (unlabelled), being sure to do so by referencing the lengths through the *variables* to which they are bound.
8. Run the program.

Task 6: `Point C` programming

For this task you will want to use the `indexOf` method of the `String` class. If you should need a hint for how to do this, simply look at the part of the `StringOps` program that computes string lengths.

1. Introduce a variable called `singerCommaPosition` and bind it to the position of the comma in the singer's name string. Be sure to arrange for the computer to compute the position of the comma.
2. Introduce a variable called `sculptorCommaPosition` and bind it to the position of the comma in the sculptor's name string. Be sure to arrange for the computer to compute the position of the comma.

3. Introduce a variable called `painterCommaPosition` and bind it to the position of the comma in the painter's name string. Be sure to arrange for the computer to compute the position of the comma.
4. Introduce a variable called `dancerCommaPosition` and bind it to the position of the comma in the dancer's name string. Be sure to arrange for the computer to compute the position of the comma.
5. Introduce a variable called `selfCommaPosition` and bind it to the position of the comma in your name string. Be sure to arrange for the computer to compute the position of the comma.
6. Add the following line of code: `System.out.println("\nComma positions ...");`
7. Add five lines of code, one to print each of the five comma positions (unlabelled), being sure to do so by referencing the comma positions through the *variables* to which they are bound.
8. Run the program.

Task 7: `Point D` programming

For this task you will want to use the 1 argument `substring` method of the `String` class. If you should need a hint for how to do this, simply look at the part of the `StringOps` program that makes use of the `substring` method with 1 argument. **Do not count and do not insert a number into the `substring` argument** – be sure to use the relevant *variable* that was bound in *Task C* of this program.

1. Introduce a variable called `singerFirst` and bind it to the first name of the singer. Be sure to arrange for the computer to compute the first name.
2. Introduce a variable called `sculptorFirst` and bind it to the first name of the sculptor. Be sure to arrange for the computer to compute the first name.
3. Introduce a variable called `painterFirst` and bind it to the first name of the painter. Be sure to arrange for the computer to compute the first name.
4. Introduce a variable called `dancerFirst` and bind it to the first name of the dancer. Be sure to arrange for the computer to compute the first name.
5. Introduce a variable called `selfFirst` and bind it to your first name. Be sure to arrange for the computer to compute the first name.
6. Add the following line of code: `System.out.println("\nFirst names ...");`
7. Add five lines of code, one to print each of the five last names (unlabelled), being sure to do so by referencing the comma positions through the *variables* to which they are bound.
8. Run the program.

Task 8: `Point E` programming

For this task you will want to use the 2 argument `substring` method of the `String` class. If you should need a hint for how to do this, simply look at the part of the `StringOps` program that makes use of the `substring` method with 2 arguments. **Do not count and do not insert a number (besides 0) into the `substring` argument** – be sure to use the relevant *variable* that was bound in *Task C* of this program.

1. Introduce a variable called `singerLast` and bind it to the last name of the singer. Be sure to arrange for the computer to compute the last name.
2. Introduce a variable called `sculptorLast` and bind it to the last name of the sculptor. Be sure to arrange for the computer to compute the last name.
3. Introduce a variable called `painterLast` and bind it to the last name of the paitner. Be sure to arrange for the computer to compute the last name.
4. Introduce a variable called `dancerLast` and bind it to the last name of the dancer. Be sure to arrange for the computer to compute the last name.
5. Introduce a variable called `selfLast` and bind it to your last name. Be sure to arrange for the computer to compute the last name.
6. Add the following line of code: `System.out.println("\nLast names ...");`

7. Add five lines of code, one to print each of the five last names (unlabelled), being sure to do so by referencing the comma positions through the *variables* to which they are bound.
8. Run the program.

Task 9: `Point F` programming

1. Toggle the comments on the six lines **following** the `Point F` comment.
2. Use the red text and light bulb to create a stub for the `firstName` method.
3. Note that IntelliJ guessed at the *type* of the `firstName` *method* we wish to define, but got it wrong with respect to our intentions. IntelliJ also did its best to come up with a reasonable *name* for the *parameter*, but came up short on this count too. You should take this opportunity to adjust its guesses by doing the following:
   (a) Change the *type* of the *method* from `boolean` to `String`.
   (b) Change the *name* of the *parameter* to `directoryStyleName`.
4. What will be the value of the parameter, `directoryStyleName`, when the `firstName` method is called with the name of the singer? Please write it down.

5. What will be the value of the parameter, `directoryStyleName`, when the `firstName` method is called with the name of the dancer? Please write it down.

6. Fill in the body of the `firstName` method so that it computes and returns the first name of the individual whose name is given by the parameter. Please note that you will find the first name by looking to the parameter!
7. Run the program.

Task 10: `Point G` programming

1. Toggle the comments on the six lines **following** the `Point G` comment.
2. Use the red text and light bulb to create a stub for the `lastName` method.
3. Edit the *header* of the `lastName` method in just the same manner that you previously edited the *header* of the `firstName` method.
4. What will be the value of the parameter, `directoryStyleName`, when the `lastName` method is called with the name of the singer? Please write it down.

5. What will be the value of the parameter, `directoryStyleName`, when the `lastName` method is called with the name of the dancer? Please write it down.

6. Fill in the body of the `lastName` method so that it computes and returns the last name of the individual whose name is given by the parameter. Please note that you will find the last name by looking to the parameter!
7. Run the program.

Task 11: `Point H` programming

1. Toggle the comments on the six lines **following** the `Point H` comment.
2. Use the red text and light bulb to create a stub for the `fullName` method.

3. Change the *type* of the `fullName` *method* to `String` and change the *name* of the *parameter* of the `fullName` method to `dsn`.
4. What will be the value of the parameter, `dsn`, when the `fullName` method is called with the name of the singer? Please write it down.

5. What will be the value of the parameter, `dsn`, when the `fullName` method is called with the name of the dancer? Please write it down.

6. Fill in the body of the `fullName` method so that it computes and returns the full name - first name followed by a space followed by the last name - of the individual whose name is given by the parameter. **CONSTRAINT: It is required that you use both the `firstName` method and the `lastName` method to define the `fullName` method.**
7. Run the program.

Task 12: Post your work

Please post your work for this lab on you Web site. Simply, post the source code and the demo for each of the two featured programs.

Task 13: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

15 Presentation: Strings

This material is presented in real time during the course lectures.

16 Lab 8: Array Play

F. Herbert (First Law of Mentat in DUNE) on UNDERSTANDING PROCESSES

A process cannot be understood by stopping it. Understanding must move with the flow of the process, must join and flow with it.

Overview

This lab features three programs. The first two programs, `Primes` and `Streets`, are merely intended to help you to wrap your minds around the basics of array creation and array element referencing. Basically, you will read the `Primes` program and write, by analogy, the `Streets` program. The third program, `ReverseCopy`, features array processing and illustrates file IO by solving a relatively realistic problem, that of reading words from one file and writing them, in reverse order, to another file. This program can serve as a model for subsequent programs that you write involving file IO. The program also contrasts use of the `while` statement and the `for` statement, introduces you to the role that *exceptions* play in computer programming, and makes limited use of *properties* associated with the `System` class.

Why do it?

As you work through this lab you will:

1. Get acquainted with *basic array processing* functionality.
2. Learn to appreciate *basic concepts* associated with doing simple *file IO*.
3. Perform some *file processing* - reading words from a file and writing words to a file.
4. Make use of *system properties* in your programming.
5. See how *exceptions* play a role in computer programming.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Study (read/create/run/reflect upon) the `Primes` program

The accompanying `Primes` program features an array of single digit primes. By design, the program doesn't do much of anything, in order that attention can be clearly focussed on the bare essentials of array processing.

1. Carefully read through the `Primes` program and the demo that follows it. (The line numbers are included for ease of subsequent referencing.)

Program: Primes (just the main method)

```
1    public static void main(String[] args) {
2
3        int[] primes = new int[4];
4
5        primes[0] = 2;
6        primes[1] = 3;
7        primes[2] = 5;
8        primes[3] = 7;
9
10       System.out.println("length of primes array = " + primes.length);
11       System.out.println("first prime = " + primes[0]);
12       System.out.println("last prime = " + primes[3]);
13       System.out.println("last prime = " + primes[primes.length-1]);
14
15       System.out.println("\nThe initial array ...");
16       int i = 0;
17       while ( i < primes.length ) {
18           System.out.println(primes[i]);
19           i = i + 1;
20       }
21
22       int temp = primes[0];
23       primes[0] = primes[primes.length-1];
24       primes[primes.length-1] = temp;
25
26       System.out.println("\nThe final array ...");
27       for ( int x = 0; x < primes.length; x = x + 1 ) {
28           System.out.println(primes[x]);
29       }
30
31   }
```

Demo: Primes

```
length of primes array = 4
first prime = 2
last prime = 7
last prime = 7

The initial array ...
2
3
5
7

The final array ...
7
3
5
2
```

2. Within a package called `arrayplay`, establish a Java Class called `Primes` with a reasonable *lead comment* (craft a simple sentence that is appropriate) and the `main` method that has been provided.
3. Run the program.
4. Take a few minutes to answer the following questions:
   (a) How does one *declare* an array variable in Java?

   (b) How does one *create* an array object containing a certain number of elements in Java?

   (c) How does one *reference* an element of an array in Java?

   (d) How do you reference the *length* of an array in Java?

   (e) What is the index of the *first* element of an array in Java?

   (f) What is the index of the *last* element of an array in Java?

Task 3: Write a `Streets` program, working by analogy with the `Primes` program

Write a program called `Streets`, bit by bit, according to the instructions which follow, working by analogy with the `Primes` program. The `Streets` program will feature names of streets that you can walk in the French Quarter of New Orleans.

1. Within the `arrayplay` package, establish a Java Class called `Streets`.
2. Change the *lead comment* to something reasonable.
3. Add a line to the `main` method of your `Streets` program to declare a `String` array called `streets` and bind it to an array capable of storing 12 `String` objects. (Work by analogy with line 3 of the `main` method of the `Primes` program, which creates an `int` array called `primes` capable of storing 4 `int` values.)
4. Place the following names of French Quarter streets into the `streets` array, in the order provided: `"Iberville"` `"Decatur"` `"Toulouse"` `"Bourbon"` `"Dauphine"` `"Royal"` `"St Ann"` `"St Peter"` `"Conti"` `"Exchange"` `"Bienville"` `"Dumaine"`. (Work by analogy with lines 5-8 of the `main` method of the `Primes` program.)
5. Run the program.
6. Mimicking the code that appears in lines 10-13 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the length of the featured array, the first element of the featured array, and the last element of the featured array, twice.
7. Run the program.
8. Mimicking the code that appears in lines 15-20 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the elements of the `streets` array.
9. Run the program.
10. Mimicking the code that appears in lines 22-24 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to swap the first element and the last element of the `streets` array.
11. Mimicking the code that appears in lines 26-29 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the elements of the `streets` array.
12. Run the program.

Task 4: Study, implement, and run a program to *reverse copy* a disk file

Consider the following program. `ReverseCopy` reads words from one file and writes them in reverse order to a second file. (In this instance, the line numbers are included merely so that you will be better able to refer to lines of the program should you wish to discuss it with someone.)

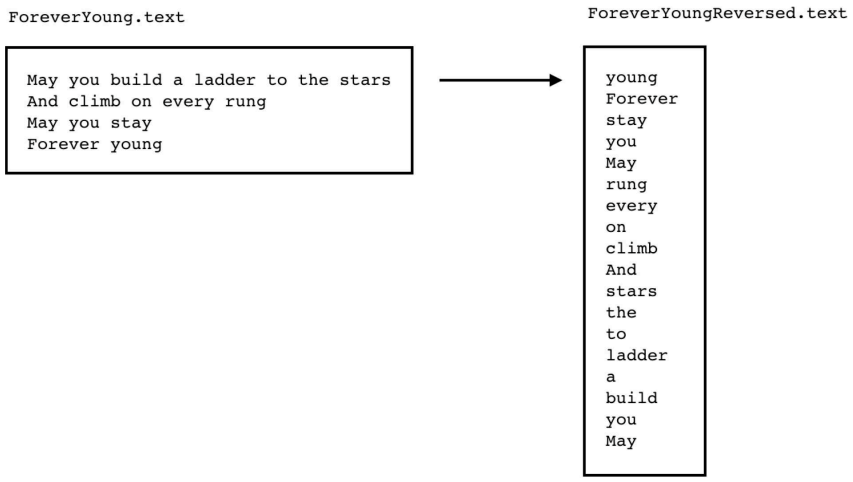
Program: `ReverseCopy`

```
1    /*
2     * Program featuring straight up arrays and file IO to read and reverse copy a lyric.
3     */
4
5    package arrayplay;
6
7    import java.io.File;
8    import java.io.FileNotFoundException;
9    import java.io.IOException;
10   import java.io.PrintWriter;
11   import java.util.Scanner;
12
13   public class ReverseCopy {
```

```
14
15      public static void main(String[] args) throws FileNotFoundException, IOException {
16          String inputFileName = "ForeverYoung.text";
17          String outputFileName = "ForeverYoungReversed.text";
18          String[] words = readWordsFromFile(inputFileName);
19          writeWordsToFile(words,outputFileName);
20      }
21
22      private static final int LIMIT = 1000;
23
24      private static String[] readWordsFromFile(String inputFileName) throws FileNotFoundException {
25          // Equate a scanner with the input file
26          Scanner scanner = establishScanner(inputFileName);
27          // Read the words from the file into an oversized array
28          String[] temp = new String[LIMIT];
29          int index = 0;
30          while ( scanner.hasNext() ) {
31              String word = scanner.next();
32              temp[index] = word;
33              index = index + 1;
34          }
35          int wordCount = index;
36          // Transfer the words to a perfectly sized array
37          String[] words = new String[wordCount];
38          for ( int x = 0; x < wordCount; x = x + 1 ) {
39              words[x] = temp[x];
40          }
41          // Return the words
42          return words;
43      }
44
45      private static void writeWordsToFile(String[] words, String outputFileName) throws IOException {
46          // Equate a printer with an output file
47          PrintWriter printer = getPrintWriter(outputFileName);
48          // Print the words to the file
49          for ( int x = words.length-1; x >= 0; x = x - 1 ) {
50              printer.println(words[x]);
51          }
52          printer.close();
53      }
54
55      private static Scanner establishScanner(String inputFileName) throws FileNotFoundException {
56          String fullFileName = createFullFileName(inputFileName);
57          return new Scanner(new File(fullFileName));
58      }
59
60      private static PrintWriter getPrintWriter(String outputFileName) throws FileNotFoundException {
61          String fullFileName = createFullFileName(outputFileName);
62          PrintWriter printer = new PrintWriter(fullFileName);
63          return printer;
64      }
65
66      // Create the full file name for a simple file name, assuming that it will be
67      // found in the CS1Files/data subdirectory of the user's home directory.
```

```
68      private static String createFullFileName(String fileName) {
69          String separator = System.getProperty("file.separator");
70          String home = System.getProperty("user.home");
71          String path = home + separator + "CS1Files" + separator + "data" + separator;
72          String fullFileName = path + fileName;
73          return fullFileName;
74      }
75
76  }
```

Illustration



Noteworthy aspects of this program

1. The partial file names are hard coded in the `main` method. This is done quite simply in order to focus without distraction on certain essential aspects of file IO. It would be a simple matter to program a more flexible mechanism for establishing file names.
2. Full file names are created very carefully, under the assumption that the input file will be found in the `data` subdirectory of the `CS1Files` subdirectory of the user's *home* directory, and that the output file will be placed in that same directory.
3. Use of the principle of stepwise refinement is clearly reflected in the structure of the program, especially with respect to the file IO.
4. A basic array is used to store the words, largely to emphasize the static nature of arrays, and by doing so set the stage for developing a deep appreciation for the `List` objects that will be featured in the next lab. Words are read into an oversized array and then transferred to a perfectly sized array.
5. A `Scanner` object is equated with the input file in order to facilitate the reading of words from the file.
6. A `PrintWriter` object is equated with the output file in order to facilitate the writing of words to the file.
7. *System properties* are incorporated into the program in the service of creating full file names.
8. The concept, and computational manifestation of, the *exception* is found to be lurking within this program.

Subtasks

1. Establish a data file.
   (a) Find yourself a lyric for some song that resonates with you, something other than "Forever Young".
   (b) Get into `Emacs`.
   (c) Establish a buffer with a reasonable name, with the intention of entering the lyric into the file.
   (d) Enter the lyric by hand into the file, stripping it of all punctuation as you do.
   (e) Check your file carefully to be sure that it contains no punctuation.
   (f) Save the file to the `data` subdirectory of the `CS1Files` subdirectory of your *home* directory.
2. Enter the `ReverseCopy` program.
   (a) Get into *IntelliJ*.
   (b) Carefully, mindfully, enter the `ReverseCopy` program as a *Java Class* program within the `arrayplay` package, changing the *file names* in the given program to *file names* appropriate to your chosen song lyric. If you are using IntelliJ in a reasonable way, your will proceed in something like the following manner:
      i. Type in the body of the main method.
      ii. Use the red text and light bulbs to *create the stubs* for the `readWordsFromFile` method and the `writeWordsToFile` method.
      iii. Add the line for the `LIMIT` constant.
      iv. Type in the body of the `readWordsFromFile` method, and as you do: click on the red text and follow the pop-up instructions to *import* the `Scanner` class, and use the red text and light bulb that appears to *create the stub* for the `establishScanner` method.
      v. Type in the body of the `writeWordsToFile` method, and as you do: click on the red text and follow the pop-up instructions to *import* the `PrintWriter` class, and use the red text and light bulb that appears to *create the stub* for the `getPrintWriter` method.
      vi. Type in the body of the `establishScanner` method, and as you do: use the light bulb that appears to *create the stub* for the `createFullFileName` method, click on the red text and follow the instructions to *import* the `File` class, and use the light bulb that appears when clicking on red-underlined text to add the *throws* clause for the `FileNotFoundException` exception to the method signature. The option to choose will say something like *Add exception to method signature*.
      vii. Type in the body of the `getPrintWriter` method, and as you do: use the light bulb that appears when clicking on red-underlined text to add the *throws* clause for the `FileNotFoundException` exception to the method signature.
      viii. Type in the body of the `createFullFileName` method, and as you do: adjust IntelliJ's guess at the *parameter name*, changing it to `fileName`, and add the *prefacing comment* as well.
      ix. Use the light bulbs appropriately to add the *throws* clauses for the `FileNotFoundException` exception to the `writeWordsToFile` method, the `readWordsFromFile` method, and the `main` method.
3. Run the program.
4. Check to see that the program did its job by looking for the output file in the `data` subdirectory of the `CS1Files` subdirectory of your *home* directory, and by checking its contents.

Task 5: Post your work

Please post your work for this lab on you Web site. Post the source code and the demo for each of the first two programs. For the third program, post the source code, the song lyric file, and the file containing the words of the lyric in reverse order.

Task 6: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

17 Presentation: Arrays, File IO, the `for` Statement

This material is presented in real time during the course lectures.

18 Lab 9a: Simple List Processing

D. Gelernter on MACHINE BEAUTY

Beauty is more important in computing than anywhere else in technology because software is so complicated. Beauty is the ultimate defense against complexity. The geniuses of the computer field are the people with the keenest aesthetic senses, the ones who are capable of creating beauty. Beauty is decisive at every level: the most important interfaces, the most important programming languages, the winning algorithms are the beautiful ones.

Overview

This lab, like the Array Play lab, features three programs. In fact, the three programs featured in this lab are clear riffs on those featured in the Array Play lab. Whereas the programs in the Array Play lab were dedicated to acquainting you with basic concepts and mechanisms associated with the *array*, the programs in this lab are dedicated to acquainting you with basic concepts and mechanisms associated with the `ArrayList`.

Why do it?

As you work through this lab you will:

1. Get acquainted with basic `ArrayList` processing functionality.
2. Have an opportunity to compare and contrast *array* processing (previous lab) with `ArrayList` processing (this lab).
3. Revisit many of the things that you were introduced to in the previous lab.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Study (read/create/run/reflect upon) the accompanying `Primes` program

The accompanying `Primes` program features an `ArrayList` of single digit primes. Like the `primes` program of the previous lab, this `primes` program doesn't do much of anything, in order that attention can be clearly focused on some bare essentials. This time, the focus in on `ArrayList` processing.

1. Carefully read through the `Primes` program and the demo that follows it. (The line numbers are included for subsequent reference purposes.)

Program: Primes (just the main method)

```
1     public static void main(String[] args) {
2
3         ArrayList<Integer> primes = new ArrayList<>();
4
5         primes.add(2);
6         primes.add(3);
7         primes.add(5);
8         primes.add(7);
9
10        System.out.println("size of primes list = " + primes.size());
11        System.out.println("first prime = " + primes.get(0));
12        System.out.println("last prime = " + primes.get(3));
13        System.out.println("last prime = " + primes.get(primes.size()-1));
14
15        System.out.println("\nThe initial list ...");
16        for ( Integer prime : primes ) {
17            System.out.println(prime);
18        }
19
20        int temp = primes.get(0);
21        primes.set(0, primes.get(primes.size()-1));
22        primes.set(primes.size()-1,temp);
23
24        System.out.println("\nThe final list ...");
25        for ( Integer prime : primes ) {
26            System.out.println(prime);
27        }
28
29    }
```

Demo: Primes

```
size of primes list = 4
first prime = 2
last prime = 7
last prime = 7

The initial list ...
2
3
5
7

The final list ...
7
3
5
2
```

2. Within a package called `arraylistplay`, establish a Java Class called `Primes` with a reasonable *lead comment* (craft a simple sentence that is appropriate) and the `main` method that has been provided.
3. Run the program.
4. Take a few minutes to answer the following questions.
   (a) How does one *declare* an `ArrayList` variable capable of storing objects of a certain type in Java.

   (b) How does one *create* an empty `ArrayList` object of a certain type in Java.

   (c) How does one *reference* an element of an `ArrayList` object in Java.

   (d) How does one *change* an element of an `ArrayList` object in Java.

   (e) How do you reference the *size* of an `ArrayList` object in Java?

   (f) What is the index of the *first* element of an `ArrayList` object in Java?

   (g) What is the index of the *last* element of an `ArrayList` object in Java?

Task 3: Write a `Streets` program, working by analogy with the `Primes` program

Write a program called `Streets`, bit by bit, according to the instructions which follow, working by analogy with the `Primes` program. The `Streets` program will feature names of streets that you can walk in the French Quarter of New Orleans.

1. Within the `arraylistplay` package, establish a Java Class called `Streets`.
2. Write a reasonable *lead comment*.
3. Create an empty `main` method.
4. Add a line to the `main` method of your `Streets` program to declare a variable called `streets` capable of storing an `ArrayList` of `String` values, and bind it to an empty array list. (Work by analogy with line 3 of the `main` method of the `Primes` program, which declares a variable called `primes` capable of storing an `ArrayList` of `Integer` values, and binds it to an empty array list.)
5. Place the following names of French Quarter streets into the `ArrayList` object to which the `streets` variable is bound, in the order provided: `"Iberville"` `"Decatur"` `"Toulouse"` `"Bourbon"` `"Dauphine"` `"Royal"` `"St Ann"` `"St Peter"` `"Conti"` `"Exchange"` `"Bienville"` `"Dumaine"`. (Work by analogy with lines 5-8 of the `main` method of the `Primes` program.)
6. Run the program.
7. Mimicking the code that appears in lines 10-13 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the length of the featured array list, the first element of the featured array list, and the last element of the featured array list, twice.
8. Run the program.
9. Mimicking the code that appears in lines 15-18 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the elements of the array list to which `streets` is bound.
10. Run the program.
11. Mimicking the code that appears in lines 20-22 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to swap the first element and the last element of the array list to which `streets` is bound.
12. Mimicking the code that appears in lines 24-27 of the `main` method of the `Primes` program, add statements to the `main` method of the `Streets` program to display, labelled, the elements of the array list to which `streets` streets is bound.
13. Run the program.

Task 4: Study, implement, and run a program to *reverse copy* a disk file

Consider the following program. Like the `ReverseCopy` program of the previous lab, this program reads words from one file and writes them in reverse order to a second file. (The line numbers are included merely so that you will be better able to refer to lines of the program should you wish to discuss it with someone.)

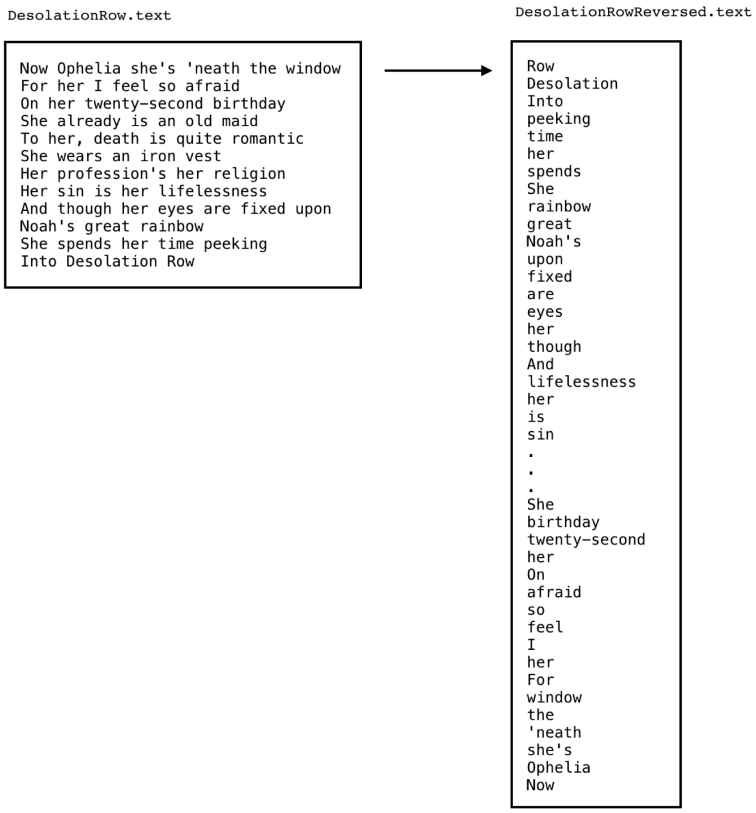
Program: `ReverseCopy`

```
1    /*
2     * This program features an ArrayList to do its reverse copy thing
3     * from one file to another.
4     */
5
6    package arraylistplay;
7
```

```
8   import java.io.File;
9   import java.io.FileNotFoundException;
10  import java.io.IOException;
11  import java.io.PrintWriter;
12  import java.util.ArrayList;
13  import java.util.Scanner;
14
15  public class ReverseCopy {
16
17      public static void main(String[] args) throws FileNotFoundException, IOException {
18          String inputFileName = "DesolationRow.text";
19          String outputFileName = "DesolationRowReversed.text";
20          ArrayList<String> words = readWordsFromFile(inputFileName);
21          writeWordsToFile(words, outputFileName);
22      }
23
24      private static ArrayList<String> readWordsFromFile(String inputFileName)
25              throws FileNotFoundException {
26          // Equate a scanner with the input file
27          Scanner scanner = establishScanner(inputFileName);
28          // Read the words from the file into a dynamically growing ArrayList
29          ArrayList<String> words = new ArrayList<>();
30          while (scanner.hasNext()) {
31              String word = scanner.next();
32              words.add(word);
33          }
34          // Return the words
35          return words;
36      }
37
38      private static void writeWordsToFile(ArrayList<String> words, String outputFileName)
39              throws IOException {
40          // Equate a printer with an output file
41          PrintWriter printer = getPrintWriter(outputFileName);
42          // Print the words to the file
43          for (int x = words.size() - 1; x >= 0; x = x - 1) {
44              printer.println(words.get(x));
45          }
46          printer.close();
47      }
48
49      private static Scanner establishScanner(String inputFileName)
50              throws FileNotFoundException {
51          String fullFileName = createFullFileName(inputFileName);
52          return new Scanner(new File(fullFileName));
53      }
54
55      private static PrintWriter getPrintWriter(String outputFileName)
56              throws FileNotFoundException {
57          String fullFileName = createFullFileName(outputFileName);
58          PrintWriter printer = new PrintWriter(fullFileName);
59          return printer;
60      }
61
```

```
62      // Create the full file name for a simple file name, assuming that it will be
63      // found in the CS1Files/data subdirectory of the user's home directory.
64      private static String createFullFileName(String fileName) {
65          String separator = System.getProperty("file.separator");
66          String home = System.getProperty("user.home");
67          String path = home + separator + "CS1Files" + separator + "data" + separator;
68          String fullFileName = path + fileName;
69          return fullFileName;
70      }
71
72  }
```

Illustration



Noteworthy aspects of this program

1. An `ArrayList` is used to store the words. By comparison with the `ReverseCopy` program of the previous lab, you should be able to appreciate the *dynamic nature of lists*.
2. The remaining bits of the program are essentially the same as in the previous version:
   (a) As with the `ReverseCopy` program of the previous lab, the file names are hard coded, in order to focus without distraction on certain basic aspects of file IO. But note that a *different lyric* is featured in this `ReverseCopy` program than was featured in the previous `ReverseCopy` program.
   (b) Full file names are created very carefully, under the assumption that the input file will be found in the `data` subdirectory of the `CS1Files` subdirectory of the user's *home* directory, and that the output file will be placed in that same directory.
   (c) Use of the *principle of stepwise refinement* is clearly reflected in the *structure of the program*.

(d) A `Scanner` object is equated with the input file in order to facilitate the reading of words from the file.
(e) A `PrintWriter` object is equated with the output file in order to facilitate the writing of words to the file.
(f) *System properties* are incorporated into the program in the service of creating full file names.
(g) The concept, and computational manifestation of, the *exception* is found to be lurking within this program.

The Subtasks

1. Establish a data file.
   (a) Find yourself a lyric for some song that resonates with you, a song that is different from the one that you used in the previous lab.
   (b) Get into `Emacs`.
   (c) Establish a buffer with a reasonable name into which you can enter the lyric.
   (d) Enter the lyric by hand into the file, stripping it of all punctuation as you do.
   (e) Check your file carefully to be sure it contains no punctuation.
   (f) Save the file to the `data` subdirectory of the `CS1Files` subdirectory of your *home* directory.
2. Enter the `ReverseCopy` program.
   (a) Get into *IntelliJ*.
   (b) Carefully, mindfully, enter the `ReverseCopy` program, changing the *file names* in the given program to *file names* appropriate to your chosen song lyric. Please do this in a way that makes reasonable use of IntelliJ!
3. Run the program.
4. Check to see that the program did its job by looking for the output file in the `data` subdirectory of the `CS1Files` subdirectory of your *home* directory, and by checking its contents.

Task 5: Post your work

Please post your work for this lab on you Web site. Post the source code and the demo for each of the first two programs. For the third program, post the source code, the song lyric file, and the file containing the words of the lyric in reverse order.

Task 6: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

19 Presentation: Streams and List Processing

This material is presented in real time during the course lectures.

20 Lab 9b: List Processing with Streams

Harold Abelson on PROGRAMMING

Programs must be written for people to read, and only incidentally for machines to execute.

Overview

In this lab you will write two programs which perform common processing tasks on list structures. Both programs will produce the same output, but will be constructed in very different ways. The first program will make use of explicit `for` loops and functions to perform operations which can easily be composed to produce more complex operations. The second will make use of streams to perform the same tasks.

Why do it?

As you work through this lab you will gain experience in doing the following things:

1. Writing small functions which transform data in one list structure into another.
2. Composing simple functions to perform more complex tasks.
3. Writing programs using Java streams.

You can think of streams as making up a kind of microworld of their own – one which focuses not on painting or music, but rather on transforming lists of data. You'll remember from class that streams may be constructed from lists, then may perform a sequence of transformations on the elements of the list. Sometimes we then collect the data from the stream in a convenient form. This lab will feature three kinds of transformations: **map**, **filter**, and **reduce**. We will also use two collectors, one which creates a `List` from the stream elements, and another which creates a `String`.

During this lab you will also gain a further understanding of the idea that there are often multiple ways to achieve the same effect in programming. We have seen how the `while` loop is more general than the `for` loop, and how in some cases the `for` loop can result in easier to write and understand code.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Prepare to refine the `ArrayListProcessing` class

1. Carefully read through the accompanying `ArrayListProcessing` program.
2. Within your package called `arraylists`, establish a Java Class called `ArrayListProcessing`. Then enter the program just as it is presented here.

Program: `ArrayListProcessing`

```
1   /*
2    * A program to perform some basic operations on a list of String names.
3    */
4
5   package arraylists;
6
7   import java.util.ArrayList;
8   import java.util.List;
9
10  public class ArrayListProcessing {
11
12      public static void main(String[] args){
13          // POINT A: Add some strings which represent names to an ArrayList.
14          List<String> names = new ArrayList<>();
15          names.add("Holiday, Billie");
16          names.add("Claudel, Camille");
17          names.add("Picasso, Pablo");
18          names.add("Gallen-Kallela, Akseli");
19          names.add("Zotto, Osvaldo");
20
21          // POINT B: Create an ArrayList of just the first names of the names
22          //          ArrayList. Use a for loop to print out the names, separated
23          //          by spaces.
24
25          // POINT C: Use String's join function to create and print a String of
26          //          just the first names of the names ArrayList with each
27          //          name separated by a comma.
28
29          // POINT D: By analogy from points B and C, print a comma-separated
30          //          list of the last names in the names ArrayList.
31
32          // POINT E: Print a comma-separated list of all uppercase first names
33          //          from the list of names in the names ArrayList.
34
35          // POINT F: Print a comma-separated list of all hyphenated last names
36          //          from the list of names in the names ArrayList.
37
38          // POINT G: Print the integer value of the total length of all names
39          //          in the names ArrayList.
40
41          // POINT H: Print the integer value of the total length of all
42          //          first names in the names ArrayList.
43
44          // POINT I: Print the integer value of the product of the length of
45          //          all first names in the names ArrayList.
46      }
47
48  }
```

Task 3: Refine the `ArrayListProcessing` class

We will now work to refine the provided class. For some points, I have provided code which you should type in to your program. For others, you will work by analogy to complete the task.

1. **Point A Refinement**
   (a) I have provided you with code which creates an `ArrayList` of `String`s called `names` and added some elements representing names to it in the format `<last_name>, <first_name>`.
   (b) Add a couple names of your own choosing in the same format.
2. **Point B Refinement**
   (a) Visit the class file for your `StringThing` program from Lab 7. Copy the `firstName` method from that class into your `ArrayListProessing` class **below the `main` method**. Recall that this function operates on a directory-style name (e.g., "Gosling, James") and returned only the first name ("James", in this example).
   (b) Re-read the `POINT B` comment in the program to get yourself into the mindset of what we're trying to accomplish.
   (c) Under the `POINT B` comment in the program, add code to which will make use of a `firstNames` function (which we will soon write), and prints out the results as prescribed by that comment. I've provided some code below which you should read and understand before typing in.

```
List<String> firstNamesList = firstNames(names);

System.out.print("First names: ");
for (String firstName : firstNamesList){
    System.out.print(firstName + " ");
}
System.out.println();
```

   (d) Write a method called `firstNames` which transforms a list of names into a list of only first names. I've provided this code for you below. Read it carefully and be sure you understand it – you'll be asked to do a similar thing shortly! Once you are sure you understand it, type it in to the `ArrayListProessing` program **below the `main` method**.

```
private static List<String> firstNames(List<String> names){
    List<String> firsts = new ArrayList<>();
    for (String name : names){
        firsts.add(firstName(name));
    }
    return firsts;
}
```

   (e) Run your program. You should see the first names printed.
3. **Point C Refinement**
   (a) As we've seen before, the Java `String` library is powerful, with many functions available to us. Today we will use the `join` function to convert a list of `String`s into a single `String`, where each string is separated by a *delimiter*. The following code joins all of the first names from our `firstNamesList` into a single comma-separated `String` called `firstNames`. Type it below the `POINT C` comment in the program.

```
String firstNames = String.join(", ", firstNamesList);

System.out.println("First names: " + firstNames);
```

   (b) Test your program and recognize how it differs from what we wrote in Point B.
   (c) Think about how you would change the code you just wrote to give a result identical to that from point B.

4. **Point D Refinement**
   (a) Work by analogy from point B to first create an `ArrayList` of only the *last* names for the names in the `names ArrayList`. Do this by copying the `lastName` function from `StringThing` and writing a new function called `lastNames` in your `ArrayListProessing` class which will be very similar (but not identical) to the `firstNames` function we already wrote.
   (b) Work by analogy from point C to use `String`'s `join` function to create a comma-separated list of last names.
   (c) Print out the list of last names.
   (d) Test your program and refine as necessary.
   (e) *Note: In this task we're treating each of the points D-I as independent, so we don't mind duplicating a bit of functionality.*
5. **Point E Refinement**
   (a) Re-read the `POINT E` comment in the program to get yourself into the mindset of what we're trying to accomplish.
   (b) Write a function below the `main` method which takes as input a list of names, and returns a new list of names where all of the names have been transformed to be all uppercase. Actually, I've already written this one for you. Read it and understand it well before typing it in to your program below the `main` method.

```
public static List<String> upperCaseNames(List<String> names){
    List<String> uppercases = new ArrayList<>();
    for (String name : names){
        uppercases.add(name.toUpperCase());
    }
    return uppercases;
}
```

   (c) Notice how this function has the same general structure as the previous two we've written: it creates a new `ArrayList` where we will put our resulting data to return, then it loops over the original data, performing some transformation, and storing the result in this new list we created. Finally the new list is returned. You can think of this function as performing a **mapping** to uppercase for each name in the provided list.
   (d) Use the method we just wrote to get the upper case first names from the list of names and print them out. Read and understand the below code before typing it in below the `POINT E` comment in the `main` method.

```
List<String> upperCaseFirstNamesList = upperCaseNames(firstNames(names));
String upperCaseFirstNames = String.join(", ", upperCaseFirstNamesList);

System.out.println("Uppercase first names: " + upperCaseFirstNames);
```

   (e) Notice how we are chaining together multiple functions which modify our initial list of names. In `upperCaseNames(firstNames(names))` we say to first get all of the first names, then make them all uppercase.
   (f) Test the program.
6. **Point F Refinement**
   (a) Re-read the `POINT F` comment in the program to get yourself into the mindset of what we're trying to accomplish.
   (b) Write a function below the `main` method which takes as input a list of names, and returns a new list of names in which only the ones which are hyphenated are retained (that is, only `String`s which contain a hyphen are returned). I've already written this one for you too. Read it and understand it well before typing it in to your program.

```
public static List<String> hyphenatedNames(List<String> names){
    List<String> hyphenateds = new ArrayList<>();
    for (String name : names){
        if (name.contains("-")) {
            hyphenateds.add(name);
        }
    }
    return hyphenateds;
}
```

(c) Again notice how the structure of the method is similar to previous ones, but it has one major difference: the use of a selection statement inside the `for` loop. This causes the method to act like a **filter** – keeping only the elements which match the condition.

(d) By analogy from the code we wrote under `POINT E`, write a few statements to get and print a comma-separated list of hyphenated last names.

(e) Test your code.

7. **Point G Refinement**

(a) Write a function below the `main` method which takes a list of names and returns the integer length of all of the names in the list. Once more, I've written this one for you. It should look somewhat familiar from examples we've done in class. Be sure you understand it before typing it in to your program.

```
public static int totalNameLength(List<String> names){
    int totalLength = 0;
    for (String name : names){
        totalLength = totalLength + name.length();
    }
    return totalLength;
}
```

(b) Notice how this function differs from the previous parts of this lab. Instead of creating a new `ArrayList` to store our result, we use an `int` which holds an initial value (0) to begin with, and is modified by processing each element in the `ArrayList`. The `int` acts as an *accumulator*. In a sense, we can think of this function as **reducing** a whole list of elements (`String`s in this case) to a single piece of data (an `int` in this case).

(c) Type the following below the `POINT G` comment in your `main` method.

```
int totalLength = totalNameLength(names);

System.out.println("Total length: " + totalLength);
```

(d) Test your program and ensure the result is correct.

8. **Point H Refinement**

(a) Work by analogy from the above points to get the total length of only the first names from the `names ArrayList`. Store the result in an appropriately named `int` variable then print it out. *You shouldn't need to write any new methods for this point.*

(b) Test your code and ensure the answer is correct.

9. **Point I Refinement**

(a) Work by analogy from point G to write a function which calculates the product of the lengths of each of the names in a list of names.

(b) Again as in point G, write some code in the appropriate spot in the `main` method to test your function.

(c) Test your function. Be sure you got the answer you expected.

Task 4: Prepare to refine the `StreamArrayListProcessing` class

1. Carefully read through the accompanying `StreamArrayListProcessing` program. The structure should look familiar, though the instructions might not.
2. Within your package called `arraylists`, establish a Java Class called `StreamArrayListProcessing`. Then enter the program just as it is presented here.

Program: `StreamArrayListProcessing`

```
1    /*
2     * A program to perform some basic operations on a list of Strings
3     * using Java streams.
4     */
5
6    package arraylists;
7
8    import java.util.ArrayList;
9    import java.util.List;
10   import java.util.stream.Collectors;
11
12   public class StreamArrayListProcessing {
13
14       public static void main(String[] args){
15           // POINT A: Add some strings which represent names to an ArrayList.
16           List<String> names = new ArrayList<>();
17           names.add("Holiday, Billie");
18           names.add("Claudel, Camille");
19           names.add("Picasso, Pablo");
20           names.add("Gallen-Kallela, Akseli");
21           names.add("Zotto, Osvaldo");
22
23           // POINT B: Use map and the toList collector to create an ArrayList of just
24           //          the first names of the names ArrayList. Use a for loop to print
25           //          out the names, separated by spaces.
26
27           // POINT C: Use map and the joining collector to create a String of just
28           //          the first names of the names ArrayList with each name separated
29           //          by a comma. Print it.
30
31           // POINT D: By analogy from point C, print a comma-separated list of the
32           //          last names in the names ArrayList.
33
34           // POINT E: Print a comma-separated list of all uppercase first names
35           //          from the list of names in the names ArrayList.
36
37           // POINT F: Print a comma-separated list of all hyphenated last names
38           //          from the list of names in the names ArrayList.
39
40           // POINT G: Print the integer value of the total length of all names
41           //          in the names ArrayList.
42
43           // POINT H: Print the integer value of the total length of all
44           //          first names in the names ArrayList.
```

```
45
46          // POINT I: Print the integer value of the product of the length of
47          //          all first names in the names ArrayList.
48      }
49
50  }
```

Task 5: Refine the `StreamArrayListProcessing` class

As before, we will now work to refine the provided class. For some points, I have provided code which you should type in to your program. For others, you will work by analogy to complete the task. You will want to have your `ArrayListProcessing` class handy to compare what we do here with what we did there.

1. **Point A Refinement**
   (a) Revisit, for a moment, your `ArrayListProcessing` class and copy the additions you made to the `names ArrayList` into your new class.
2. **Point B Refinement**
   (a) Once again, copy the `firstName` function from your `StringThing` program into the class you're working on now.
   (b) Instead of using a method to perform an operation on each element of our `names` list as we did in Task 3, we will use *streams*. Consider the following:

```
List<String> firstNamesList = names.stream()
    .map(n -> firstName(n))
    .collect(Collectors.toList());

System.out.print("First names: ");
for (String firstName : firstNamesList){
    System.out.print(firstName + " ");
}
System.out.println();
```

   Here, the transformation from the `firstNames` function in the previous program is captured by the `map` function.
   (c) Type the above code below the `POINT B` comment. Make sure you understand how the program works.
   (d) Run the program and ensure it produces the same answer as your previous program.
3. **Point C Refinement**
   (a) Modify a copy of the code from Point B to use the `joining` collector, which performs a similar function as the `String.join` which we used in the `ArrayListProcessing` class. I've written this one for you, so you should study the difference between what we wrote in Point B and in previous tasks. Type this code below the `POINT C` comment.

```
String firstNames = names.stream()
    .map(n -> firstName(n))
    .collect(Collectors.joining(", "));

System.out.println("First names: " + firstNames);
```

   (b) *Note: In this task we're treating each of the points B-I as independent, so we don't mind duplicating a bit of functionality.*
   (c) Run the program and ensure it produces the same answer as your previous program.
   (d) Describe below, in your own words, what `map` does.

4. **Point D Refinement**
   (a) Work by analogy from point C to write a statement using streams which creates a comma-separated `String` of the last names from the `names ArrayList`. Do this by copying the `lastName` function from `StringThing` and modifying the stream statement from Point C to get last names instead of first names.
   (b) Print out the list of last names.
   (c) Run the program and ensure it produces the same answer as your previous program.
5. **Point E Refinement**
   (a) Write a stream expression which produces a comma-separated `String` of uppercase first names from the `names ArrayList`. Do this by writing a stream expression which uses two `map` functions. First get the first name of each name in the `names ArrayList`, then convert them to upper case, and finally use the `joining` collector to create a comma-separated `String` which lists each of the results. Print the results. Once again I've written this one for you – once you understand it, type it under `POINT E` in your class file.

```
String upperCaseFirstNames = names.stream()
    .map(n -> firstName(n))
    .map(n -> n.toUpperCase())
    .collect(Collectors.joining(", "));

System.out.println("Uppercase first names: " + upperCaseFirstNames);
```

   (b) Examine the differences between what we wrote here, and what we wrote for Point E in the `ArrayListProcessing` class. Ruminate upon the advantages to each approach.
   (c) Run the program and ensure it produces the same answer as your previous program.
6. **Point F Refinement**
   (a) Write a stream expression which produces a comma-separated `String` of the hyphenated last names in the `names ArrayList`. Do this by writing a stream expression which uses a `map` function to get the last name of each name in the `names ArrayList`, uses a `filter` function to keep only those last names which contain hyphens, and finally uses a `joining` collector. Once again I've written this one for you – once you understand it, type it under `POINT F` in your class file.

```
String hyphenatedLastNames = names.stream()
    .map(n -> lastName(n))
    .filter(n -> n.contains("-"))
    .collect(Collectors.joining(", "));
```

   (b) Write a print statement to output the results.
   (c) Notice that in the directions for Point F in Task 3 we discussed that the operation we were performing was a kind of filter. Here this is made explicit – only those items which pass the filter are retained.
   (d) Run the program and ensure it produces the same answer as your previous program.
   (e) Think about when it is appropriate to use `map` as compared to when it is appropriate to use `filter`. Write your answer here:

7. **Point G Refinement**
   (a) Write a stream expression which produces the total length of all of the names in the `names ArrayList`. Do this by using `map` to get the length of each name, then by using `reduce` to add of these lengths together. One last time, I've written this one for you. Be sure you understand the code below before you type it in. `Reduce` is notoriously difficult to understand!

```
int totalLength = names.stream()
    .map(n -> n.length())
    .reduce(0, (n1, n2) -> n1 + n2);

System.out.println("Total length: " + totalLength);
```

   (b) Run the program and ensure it produces the same answer as your previous program.
   (c) Describe below, in your own words, what `reduce` does.

8. **Point H Refinement**
   (a) Work by analogy from the above points to write a stream expression to get the total length of only the first names from the `names ArrayList`. Store the result in an appropriately named `int` variable then print it out. Place this in the obvious spot in the program.
   (b) Run the program and ensure it produces the same answer as your previous program.
9. **Point I Refinement**
   (a) Work by analogy from point G to write a stream expression which calculates the product of the lengths of each of the names in a list of names. Store the result in an appropriately named `int` variable then print it out. Place this in the obvious spot in the program.
   (b) Run the program and ensure it produces the same answer as your previous program.

Task 6: Post your work

Please post your work for this lab on you Web site. Post the source code and the demo for both of the programs.

Task 7: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

21 Presentation: Generics and Simple List Processing

This material is presented in real time during the course lectures.

22 Lab 10: Establishing and Using Classes

D. Knuth on THE UTILITY OF TOY PROBLEMS

The educational value of a problem given to a student depends mostly on how often the thought processes that are invoked to solve it will be helpful in later situations. It has little to do with how useful the answer to the problem may be. On the other hand, a good problem must also motivate the students; they should be interested in seeing the answer. Since students differ so greatly, I cannot expect everyone to like the problems that please me.

Overview

This lab features two programs. The first program, `Die`, is a *class* which models a die – an object of chance that you tend to `roll`. The second program, `Roller`, creates and uses `Die` objects – instances of the `Die` class.

Why do it?

As you work through this lab you will:

1. Learn something about modeling classes of objects.
2. Gain additional practice in creating and using computational objects.
3. "Mechanically" translate from a `for` statement to a `while` statement.

Conceivable demo for the eventual `Roller` program

```
run:
Roll a standard die 5 times ...
2 6 5 6 5
Roll a twenty sided die 5 times ...
18 9 10 4 7
Roll a standard die 20 times ...
6 1 5 2 3 1 4 6 6 1 4 1 1 4 1 4 4 2 2 4
Roll a standard die 30 times ...
4 2 1 6 5 1 6 6 5 2 6 5 1 2 5 4 5 4 5 5 6 5 3 2 5 4 6 4 6 1
Roll a nine sided die 20 times ...
9 4 4 3 2 5 4 4 6 5 1 5 8 4 5 1 7 3 9 8
Roll a nine sided die 30 times ...
8 4 6 7 4 5 4 7 8 7 1 9 4 2 7 4 1 9 4 2 2 1 9 1 9 9 5 6 5 4
Ten times, roll a stanard die for a 1.
3 2 3 1
4 4 2 2 3 6 5 5 6 6 3 6 1
4 5 5 4 4 2 1
```

```
5 6 6 5 4 3 6 1
4 3 2 6 6 5 2 5 1
2 4 5 5 2 3 1
4 5 2 6 2 6 5 2 1
6 1
1
4 4 1
Ten times, roll a twelve sided die for a 1.
3 8 8 4 12 9 9 10 10 8 6 6 2 9 11 11 1
9 3 1
3 10 10 5 5 11 10 3 1
9 1
3 11 9 7 5 1
7 12 7 2 6 9 11 2 10 9 10 1
9 9 5 10 7 4 9 7 11 5 12 2 6 5 5 8 6 3 4 8 8 8 2 8 9 6 12 4 8 2 12 1
4 2 12 1
12 9 10 3 11 5 4 1
10 2 6 7 1
BUILD SUCCESSFUL (total time: 0 seconds)
```

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Create the `Die` class

Within a package called `chance`, *mindfully* establish a Java Class called `Die` that looks like the following program:

```
/*
 * Model a die in terms of two properties:
 * - order, the number of faces
 * - top, the value of the top face
 */

package chance;

public class Die {

    // THE INSTANCE VARIABLES (STATE)

    private int order;
    private int top;

    // THE CONSTRUCTORS

    public Die() {
        order = 6;
        top = (int) ( ( Math.random() * 6 ) + 1);
    }
```

```
    public Die(int nrOfSides) {
        order = nrOfSides;
        top = (int) ( ( Math.random() * nrOfSides ) + 1);
    }

    // THE METHODS (BEHAVIOR)

    public int top() {
        return top;
    }

    public void roll() {
        top = (int) ( ( Math.random() * order ) + 1);
    }

}
```

Task 3: Create the `Roller` program

Within a package called `chanceapps`, establish a Java Class called `Roller`. One might call `Roller` a *Java Main Class* – it is one which can be executed because it has a `main` method (note that `Die` does not). *Mindfully* write the `Roller` class so that it looks like the following program:

```
/*
 * Program to make use of the Die class.
 */

package chanceapps;

import chance.Die;

public class Roller {

    public static void main(String[] args) {
        // CREATE A STANDARD DIE AND ROLL IT 5 TIMES
        createAndRollStandardDieFiveTimes();
        // CREATE A TWENTY SIDED DIE AND ROLL IT 5 TIMES
        createAndRollTwentySidedDieFiveTimes();
        // CREATE A STANDARD DIE AND ROLL IT 20 TIMES
        createAndRollStandardDie(20);
        // CREATE A STANDARD DIE AND ROLL IT 30 TIMES
        createAndRollStandardDie(30);
        // CREATE A NINE SIDED DIE AND ROLL IT 20 TIMES
        createAndRollNineSidedDie(20);
        // CREATE A NINE SIDED DIE AND ROLL IT 30 TIMES
        createAndRollNineSidedDie(30);
        // TEN TIMES, CREATE A STANDARD DIE AND ROLL IT UNTIL YOU GET A 1
        // System.out.println("Ten times, roll a standard die for a 1.");
        for (int i = 1; i <= 10; i++) {
            createAndRollStandardDieFor1();
        }
```

```
        // TEN TIMES, CREATE A TWELVE SIDED DIE AND ROLL IT UNTIL YOU GET A 1
        // System.out.println("Ten times, roll a twelve sided die for a 1.");
        for (int i = 1; i <= 10; i++) {
            createAndRollTwelveSidedDieFor1();
        }
    }

    private static void createAndRollStandardDieFiveTimes() {
        System.out.println("Roll a standard die 5 times ...");
        Die die = new Die();
        die.roll(); System.out.print(die.top() + " ");
        die.roll(); System.out.print(die.top() + " ");
        die.roll(); System.out.print(die.top() + " ");
        die.roll(); System.out.print(die.top() + " ");
        die.roll(); System.out.print(die.top() + " ");
        System.out.println();
    }

    private static void createAndRollTwentySidedDieFiveTimes() {
        throw new UnsupportedOperationException("Not supported yet.");
    }

    private static void createAndRollStandardDie(int nrOfTimes) {
        throw new UnsupportedOperationException("Not supported yet.");
    }

    private static void createAndRollNineSidedDie(int nrOfTimes) {
        throw new UnsupportedOperationException("Not supported yet.");
    }

    private static void createAndRollStandardDieFor1() {
        throw new UnsupportedOperationException("Not supported yet.");
    }

    private static void createAndRollTwelveSidedDieFor1() {
        throw new UnsupportedOperationException("Not supported yet.");
    }

}
```

Task 4: Run / study the `Roller` program

Run the `Roller` program. Take a look at the output, including the output associated with the exception that was thrown. Can you anticipate the tasks that are awaiting you?

Task 5: Refine the `createAndRollTwentySidedDieFiveTimes` method

1. Replace the `throw` statement in the `createAndRollTwentySidedDieFiveTimes` method so that the method does what its name suggests. Work by *direct analogy* with the `createAndRollStandardDieFiveTimes` method. Just be sure to create a twenty sided die with the "nonstandard" constructor rather than a standard die with the "standard" constructor.
2. Run the `Roller` program.

Task 6: Reflection / rewriting

1. Consider the `createAndRollStandardDieFiveTimes` method. Does the way it is written invite you to think of an alternative way of writing it? In the space provided below (not in IntelliJ), rewrite the method *replacing* the five identical lines with a `for` statement that accomplishes the exact same task.

2. Consider the `createAndRollTwentySidedDieFiveTimes` method. Does the way it is written invite you to think of an alternative way of writing it? In the space provided below (not in IntelliJ), rewrite the method *replacing* the five identical lines with a `for` statement that accomplishes the exact same task.

Task 7: Refine the `createAndRollStandardDie` method

1. Replace the `throw` statement in the `createAndRollStandardDie` method so that the method creates and rolls a standard die the number of times specified by the value of the parameter. In doing so, simply enter the following code:

Code for the `createAndRollStandardDie` method

```
System.out.println("Roll a standard die " + nrOfTimes + " times ...");
Die lucky = new Die();
for (int i = 1; i <= nrOfTimes; i = i + 1) {
    lucky.roll();
    System.out.print(lucky.top() + " ");
}
System.out.println();
```

2. Run the `Roller` program.

Task 8: Translate the `for` statement to a `while` statement

1. Study the code in the `createAndRollStandardDie` method. Note the existence of a `for` statement. Change the `for` statement to a `while` statement in such a way that the behavior of the method is exactly the same. Rather than simply discarding the `for` statement and writing a `while` statement from scratch, perform a "mechanical translation" based on the following mapping of a `for` abstraction to a `while` abstraction:

Mechanical procedure for translating `for` to `while`

The for statement ...

```
for (INITIALIZATION; TEST; CHANGE) {
   STATEMENT-SEQUENCE
}
```

can be written in terms of the while statement ...

```
INITIALIZATION
while (TEST) {
   STATEMENT-SEQUENCE
   CHANGE
}
```

---

2. In order to assure yourself that you actually performed the mechanical translation correctly, run the `Roller` program.

Task 9: Refine the `createAndRollNineSidedDie` method

1. Replace the `throw` statement in the `createAndRollNineSidedDie` method so that the method does what its name suggests. Work by direct analogy with the `createAndRollStandardDie` method, as modified in the previous task.
2. Run the `Roller` program.

Task 10: Refine the `createAndRollStandardDieFor1` method

1. Toggle the comment in the main method that reports the impending roll of a standard die for a 1 ten times.
2. Replace the `throw` statement in the `createAndRollStandardDieFor1` method so that the method does what its name suggests. In doing so, base your Java code on the following pseudocode:

Pseudocode to roll a standard die for a 1

```
create the die
roll the die
print the top face of the die followed by a space -- using print rather than println
while ( the top face is not a 1 ) do the following
   roll the die
   print the top face of the die followed by a space -- using print rather than println
end of the while
issue a println command (just to terminate printing on the line)
```

3. Run the `Roller` program.

Task 11: Refine the `createAndRollTwelveSidedDieFor1` method

1. Toggle the comment in the main method that reports the impending roll of a twelve sided die for a 1 ten times.
2. Replace the `throw` statement in the `createAndRollTwelveSidedDieFor1` method so that the method does what its name suggests. Work by analogy with the `createAndRollStandardDieFor1` method.
3. Run the `Roller` program.

Task 12: Post your work

Please post your work for this lab on you Web site. Post the source code for `Die` and `Roller`. Post the final run of the `Roller` program as a demo.

Task 13: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

23 Presentation: Class Definition, Interface Implementation

This material is presented in real time during the course lectures.

24 Lab 11: Modeling Objects with Classes

D. Gelernter on OBJECT-ORIENTED PROGRAMMING

Object-oriented programming as it emerged in Simula 67 allows software structure to be based on real-world structures, and gives programmers a powerful way to simplify the design and construction of complex programs.

Overview

In this lab you are guided through the process of writing a class to model a person. The `Person` class will have 5 instance variables and one constructor. Initially, it will have just one method, the `toString` method. You will be given instruction on how to write a program, `PersonDemo1`, to test this class in its initial form.

You will then be introduced to the idea of defining and implementing a *Java interface*. You will be guided through the process of enhancing the initial `Person` class by *implementing* the interface for the class. Along with this modification to the `Person` class, you will be instructed on how to modify the `PersonDemo1` test program in order to assure that the additional functionality is working.

Finally, you will be asked to write an alternate version of the test program, `PersonDemo2`, one which features an array of `Person` objects.

Why do it?

As you work through this lab you will:

1. Craft a *class* more or less from scratch (model an object).
2. *Establish a Java interface.*
3. *Implement a Java interface.*
4. Write *test programs.*
5. Engage in the process of *incremental program development.*
6. Practice using *arrays of objects.*

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.
2. Get into *IntelliJ.*
3. Open the `CS1` project, if need be.
4. Note that the tasks in this lab start out being very short. Please don't be unnerved by this!

Task 2: Establish a `Person` Java Class file

Within a package called `people`, establish a new Java Class file called `Person` in which to model a person (i.e., in which to develop a class which can be used to represent `Person` objects).

Task 3: Write the lead comment

Write a lead comment to reflect the fact that this program will model a person in terms of five properties, first name and last name (`String` values), month, day, and year of birth (`int` values).

Task 4: Recall the basic approach to modeling a class

When writing a class you must: (1) establish instance variables, (2) define any nontrivial constructors, and (3) define some number of methods. Just be mindful of this as you proceed.

Task 5: Establish the instance variables

Within the class, establish the five instance variables by means of five distinct variable declarations, using the qualifier `private` for each. Call the instance variables `firstName`, `lastName`, `month`, `day`, and `year`. Here is one of the five lines:

```
private String firstName;
```

Task 6: Define a constructor

Define a constructor with **four** parameters. The first will be a `String` called `name`, and will represent a name as a first name followed by a space followed by a last name. For example, `name` might be bound to `"William Smith"`, or `name` might be bound to `"Maggie Jones"`. The second will be an `int` called `month`, the third will be an `int` called `day`, and the fourth will be an `int` called `year`. Your job within this constructor will be to bind the **five** instance variables to appropriate values. The most interesting aspect of writing this constructor is that you will have to extract the first name from the `name` parameter and also the last name from the `name` parameter in order to bind the values of the `firstName` and `lastName` instance variables. (You should have plenty of experience doing this sort of thing from your engagement in the *String Thing* lab.) Also of interest is the fact that you will have to disambiguate like named instance variables and parameters using: `this`.

Task 7: Define a parameterless `toString` method

This public method will simply return a `String` value of the form "*FIRST LAST*, born *MONTH*/*DAY*/*YEAR*", where the *SLANTEDCAPS* words are intended to be replaced by the values of the appropriate instance variables for the object.

Task 8: Establish a demo program for the `Person` class

Create a `PersonDemo1` Java Main Class within your `people` package which is a completion of the following *partial* program in that it will create and textually display six `Person` objects, one for Bob Dylan, one for Noomi Rapace, one for Pharrell Williams, one for Frank Sinatra, one for Diana Krall, and one for you.

`PersonDemo1` Program

```
/*
 * PersonDemo1 is a simple program to create and textually display Person
 * objects.
 */

package people;

public class PersonDemo1 {

    public static void main(String[] args) {

        // CREATE THE SIX PERSON OBJECTS
        Person bd = new Person("Bob Dylan",5,24,1941);
        Person nr = new Person("Noomi Rapace",12,28,1974);
        ...
        ...
        ...
        ...

        // DISPLAY THE SIX PERSON OBJECTS TO THE STANDARD OUTPUT STREAM
        System.out.println(bd);
        System.out.println(nr);
        ...
        ...
        ...
        ...

    }

}
```

You will know that your `Person` class is correct if your output is consistent with the following sketch:

Sketch execution of `PersonDemo1`

```
Bob Dylan, born 5/24/1941
Noomi Rapace, born 12/28/1974
...
...
...
...
```

Task 9: Create the `PersonSpecification` Java interface

An **interface** with respect to the Java programming language is essentially a store of method headers. A class can **implement** an interface by defining all of the methods specified in the interface. In this task, you are to establish a Java interface that you will be asked to implement in the next task.

1. Create a Java interface ...
   (a) Right click on the `people` package and create a new `Java Class`.
   (b) On the *New Java Class* form that appears ...
      i. Type `PersonSpecification` into the *Name* field.
      ii. Select `Interface`.
      iii. Press the Enter key on the keyboard.
2. Modify the template so that it matches the following:

`PersonSpecification` interface

```
/*
 * Person functionality
 */

package people;

public interface PersonSpecification {
    public String firstName();
    public String lastName();
    public int month();
    public int day();
    public int year();
    public String initials();
    public boolean isBoomer();
}
```

Task 10: Implement the `PersonSpecification` interface in the `Person` class

Perform the implementation of the `PersonSpecification` interface in the `Person` class according to the following three step process.

1. Change the opening line of `Person` class so that you are obligated to define all of the methods represented in the `PersonSpecification`:
   - *FROM*: public class Person {
   - *TO*: public class Person implements PersonSpecification {
2. Notice that the opening line of the `Person` class is now underlined in red. Click on it, and ask the light bulb to *Implement methods*. When you select that option, a window will appear asking you which methods from the interface you would like to add stubs for. Simply click OK and IntelliJ will generate a stub for each of the methods.
3. Refine each stub in a manner consistent with the following semantics:
   - *`Person`*`.firstName()` $\longrightarrow$ *`String`*
     returns the value to which the `firstName` instance variable is bound
   - *`Person`*`.lastName()` $\longrightarrow$ *`String`*
     returns the value to which the `lastName` instance variable is bound

- *Person*`.month()` $\longrightarrow$ *int*
  returns the value to which the `month` instance variable is bound
- *Person*`.day()` $\longrightarrow$ *int*
  returns the value to which the `day` instance variable is bound
- *Person*`.year()` $\longrightarrow$ *int*
  returns the value to which the `year` instance variable is bound
- *Person*`.initials()` $\longrightarrow$ *String*
  returns the two character string consisting of the first letter of the first name followed by the first letter of the last name, both in upper case
- *Person*`.isBoomer()` $\longrightarrow$ *boolean*
  returns the value `true` is the person is a baby boomer, `false` if not

Task 11: Modify the `PersonDemo1` program

Modify the `PersonDemo1` Java Main Class file within your `people` package so that it is the reasonable completion of the following *partial* program

Revised `PersonDemo1` program

```
/*
 * PersonDemo1 is a simple program to create and textually display Person
 * objects, together with initials and an indication of whether or not the
 * person is a baby boomer.
 */

package people;

public class PersonDemo1 {

    public static void main(String[] args) {

        // CREATE THE SIX PERSON OBJECTS
        Person bd = new Person("Bob Dylan",5,24,1941);
        Person nr = new Person("Noomi Rapace",12,28,1974);
        ...
        ...
        ...
        ...

        // DISPLAY THE SIX PERSON OBJECTS TO THE STANDARD OUTPUT STREAM
        System.out.println(bd + " " + bd.initials() + " " + bd.isBoomer());
        System.out.println(nr + " " + nr.initials() + " " + nr.isBoomer());
        ...
        ...
        ...
        ...

    }

}
```

You will know that your `Person` class is correct if your output is consistent with the following sketch:

Sketch execution of the revised `PersonDemo1` program

```
Bob Dylan, born 5/24/1941 BD false
Noomi Rapace, born 12/28/1974 NR false
...
...
...
...
```

Task 12: Create the `PersonDemo2` Java Main Class File

Create a `PersonDemo2` Java Main Class file within your `people` package. This program will behave quite like the `PersonDemo1` program. It will differ in that this program's `Main` method will feature an array of `Person` objects. The form of this method will be:

```
// CREATE AN ARRAY OF PERSON OBJECTS OF SIZE 6 AND FILL IT WITH THE DATA
...
// USE A FOR LOOP TO DISPLAY THE SIX PERSON OBJECTS IN THEIR TEXTUAL FORM
...
```

Task 13: Post your work

Please post your work for this lab on you Web site. Post the source code for `PersonSpecification`, `Person`, `PersonDemo1` and `PersonDemo2`. Post the final run of the `PersonDemo1` program and the run of the `PersonDemo2` program as demos.

Task 14: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

25 Presentation: Data Modeling, Abstract Classes

This material is presented in real time during the course lectures.

26 Lab 12: Grapheme to Color Synesthesia

Seymour Papert on THE SIGNIFICANCE OF LEARNING TO PROGRAM

My basic idea is that programming is the most powerful medium of developing the sophisticated and rigorous thinking needed for mathematics, for grammar, for physics, for statistics, for all the "hard" subjects. In short, I believe more than ever that programming should be a key part of the intellectual development of people growing up.

Overview

This lab features a program that simulates grapheme to color synesthesia. It takes the form of an interpreter. Two parallel arrays are featured in the grapheme to color mapping. Strings and arrays cooperatively perform the essential elements of the computation. The *simple painter* class easily supports the graphics processing.

Why do it?

As you work through this lab you will:

1. Experience programming with *parallel arrays*.
2. Get acquainted with *sequential search*.
3. Focus yet again on the process of *interpretation*.
4. See some interesting *interactions* between *strings* and *arrays*.
5. Appreciate how the painter can render text *synesthetically*.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

1. Log on to a sanctioned machine.

2. Get into *IntelliJ*.
3. Open the `CS1` project, if need be.

Task 2: Create the `GraphemeToColorSynesthesia` program

Within a package called `synesthesia`, establish the following Java Class program, which simulates grapheme to color synesthesia. Please do so in a *mindful* manner!

`GraphemeToColorSynesthesia` program

```
/*
 * Program to simulate the phenomenon known as grapheme to color synesthesia.
 * This program is written as an interpreter that recognizes and responds to:
 * - exit | terminate the program
 * - remap | redefine the mapping from letters to colors
 * - WORD OR PHRASE | simply show the word or phrase in synesthetic color
 */

package synesthesia;

import java.awt.Color;
import java.awt.Point;
import javax.swing.JOptionPane;
import javax.swing.SwingUtilities;
import painter.SPainter;

public class GraphemeToColorSynesthesia {

    private static final int fontsize = 30;
    private static final String theLetters = "AEIOU";
    private static String[] letters;
    private static Color[] colors;

    private void paintingCode() {

        // INITIALIZATION
        SPainter miro = new SPainter(1200,220);
        miro.setScreenLocation(30, 30);
        miro.setFontSize(fontsize);
        initializeColorMap(theLetters);

        // INTERPRETATION
        while ( true ) {
            String input = JOptionPane.showInputDialog(null,
                    "Please enter a word, or a few words ...");
            if ( input == null ) { input = "EXIT"; }
            input = input.toUpperCase();
            if ( input.equals("EXIT") ) {
                break;
            } else if ( input.equals("REMAP") ) {
```

```
            initializeColorMap(theLetters);
            showLetters(miro,theLetters);
        } else {
            showLetters(miro,input.toUpperCase());
        }
    }
    miro.end();
}

private static void showLetters(SPainter miro, String input) {
    // READY
    eraseWhiteBoard(miro);
    // SET
    miro.moveTo(new Point.Double(100,100));
    // GO
    for ( int i = 0; i < input.length(); i = i + 1 ) {
        String letter = input.substring(i, i+1);
        Color color = getLetterColor(letter);
        miro.setColor(color);
        miro.draw(letter);
        miro.mrt(fontsize);
    }
}

private static void initializeColorMap(String specialLetters) {
    letters = new String[specialLetters.length()];
    colors = new Color[specialLetters.length()];
    for ( int i = 0; i < specialLetters.length(); i = i + 1) {
        letters[i] = specialLetters.substring(i,i+1);
        colors[i] = randomColor();
    }
}

private static Color getLetterColor(String letter) {
    for ( int i = 0; i < letters.length; i =i + 1 ) {
        if ( letter.equalsIgnoreCase(letters[i]) ) {
            return colors[i];
        }
    }
    return Color.BLACK;
}

private static Color randomColor() {
    int rv = (int)(Math.random()*256);
    int gv = (int)(Math.random()*256);
    int bv = (int)(Math.random()*256);
    return new Color(rv,gv,bv);
}

private static void eraseWhiteBoard(SPainter miro) {
    miro.setColor(Color.WHITE);
    miro.wash();
    miro.paintFrame(Color.black, 5);
}
```

```
    // INFRASTRUCTURE FOR SOME SIMPLE PAINTING
    public GraphemeToColorSynesthesia() {
        paintingCode();
    }

    public static void main(String[] args) {
      SwingUtilities.invokeLater(new Runnable() {
         public void run() {
            new GraphemeToColorSynesthesia();
         }
      });
    }

}
```

Task 3: Study the program

The program makes use of *parallel arrays* to store the grapheme to color synesthetic knowledge. Although this is a very basic form of knowledge representation, parallel arrays can be *practically* useful on occasion, and *theoretically* interesting as a basis for comparison with more sophisticated knowledge representations.

1. Write down, in English, at the level of the array and the array element, a description of the `initializeColorMap` method.

2. Write down, in English, at the level of the array and the array element, a description of the `getLetterColor` method.

3. Write down, in English, at the level of the array and the array element, a description of the `showLetters` method.

Task 4: Run the program

Enter different words and short phrases. Occasionally issue the `remap` command. Eventually enter the `exit` command.

Task 5: Extend the program

Change the program so that it will map all of the letters of the alphabet to colors, not just the vowels. (Once you determine what to do, it should take you about 4 seconds to do this.)

Task 6: Run the program

Enter different words and short phrases. Occasionally issue the `remap` command. Eventually enter the `exit` command.

Task 7: Post your work

Please post your work for this lab on you Web site. Post the source code for the `GraphemeToColorSynesthesia` program, and at least one snapshot of text with all of its letters colored.

Task 8: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

27 Presentation: Synesthesia, Chromesthesia

This material is presented in real time during the course lectures.

28 Lab 13: Chromesthesia

James Lovelock on COMPUTER PROGRAMMING AND LEARNING TO PROGRAM

Composing computer programs to solve scientific problems is like writing poetry. You must choose every word with care and link it with the other words in perfect syntax. There is no place for verbosity or carelessness. To become fluent in a computer language demands almost the antithesis of modern loose thinking. It requires many interactive sessions, the hands-on use of the device. You do not learn a foreign language from a book, rather you have to live in the country for years to let the language become an automatic part of you, and the same is true for computer languages.

Overview

In this lab you get to make good use of both the NPW and and the MMW! You will simulate the experience of a chromesthete, someone who automatically, inflexibly, maps pitch classes to colors.

The intent of the first task is largely to afford you an opportunity to study a program, by which I mean study certain computational constructs used in context. The program can play notes chromestetically, but only for a subset of the pitch classes that make up the most standard of scales, and only for a single note duration. The second task asks that you extend the program so that all pitch classes of the scale can be rendered. The third task invites you extend the program so that the notes can be played with a variety of durations. Taken as a whole, this lab illustrates the process of *incremental programming*.

Why do it?

As you work through this lab you will:

1. Gain experience with the technique of *incremental programming*.
2. Play with *arrays of objects*.
3. Get acquainted with a *music knowledge representation*.
4. Contribute the development of a multi-sensory program - a *chromesthetic* program, in particular.

Task 1: Create version 0 of the *Chromesthesia* program

1. FYI, the code featured in this lab is substantial enough that I have placed it right at the end of this lab. Look for it, both the *Chromesthesia* Java Main Class and the *Pitch* Java Class, at the end of this lab when you are asked to refer to *the accompanying code*.
2. Within a package called `chromesthesia0` of your `CS1` project, establish the accompanying `Chromesthesia` program as a *Java Main Class*.
3. Within the `chromesthesia0` package, establish the accompanying `Pitch` program as a *Java Class*.
4. Run the `Chromesthesia` program, and enter one of the following lines, in turn, each time the text input box appears:

(a) `C, D, E, C D E c d e`
(b) `C, C c D, D d E, E e`
(c) `C D E F G`
(d) `C C D D E E F F G F E D C C C C`
(e) `EXIT`

Task 2: Create version 1 of the *Chromesthesia* program

1. Within a package called `chromesthesia1` of your `CS1` project, establish a program called `Chromesthesia` as a *Java Main Class*. Replace all of the text within this `Chromesthesia` program of the `chromesthesia1` package with all of the text within the `Chromesthesia` program of the `chromestisia0` package.
2. Within the `chromesthesia1` package of your `CS1` project, establish a program called `Pitch` as a *Java Class*. Replace all of the text within the `Pitch` program of the `chromesthesia1` package with all of the text within the `Pitch` program of the `chromestisia0` package.
3. Edit in the few obvious places. Run the `Chromesthesia` program of the `chromesthesia1` package, and check it out to make sure that it works just like the `Chromesthesia` program of the `chromesthesia0` package. If it does, good. If not, fix things so that it does. Once everything is in order, you are in a position to carry on with the development of the program within the `chromesthesia1` package.
4. Extend the `Pitch` class so that it processes the three notes `F,` and `F` and `f`. Choose a nice color for this pitch class. Also, extend the `establishPitches` method of the `Chromesthesia` class. *Test the program.*
5. Extend the `Pitch` class so that it processes the three notes `G,` and `G` and `g`. Choose a nice color for this pitch class. Also, extend the `establishPitches` method of the `Chromesthesia` class. *Test the program.*
6. Extend the `Pitch` class so that it processes the three notes `A,` and `A` and `a`. Choose a nice color for this pitch class. Also, extend the `establishPitches` method of the `Chromesthesia` class. *Test the program.*
7. Extend the `Pitch` class so that it processes the three notes `B,` and `B` and `b`. Choose a nice color for this pitch class. Also, extend the `establishPitches` method of the `Chromesthesia` class. *Test the program.*
8. Create a file in a convenient location (perhaps you will want to make just such a location for it) and enter the following lines of text – just so that you will be able to copy and paste them at will ...
   (a) `C D E F G A B c c B A G F E D C`
   (b) `C D E C C D E C E F G E F G G A G F E C G A G F E C C G, C C G, C`
   (c) `C C G G A A G F F E E D D C G G F F E E D G G F F E E D C C G G A A G F F E E D D C`
9. Run the `Chromesthesia` program, entering each of the three lines of ABC notation text that you stored in your file.

Task 3: Create version 2 of the *Chromesthesia* program

1. Within a package called `chromesthesia2` of your `CS1` project, establish as a *Java Main Class* called `Chromesthesia`. Replace all of the text within this `Chromesthesia` program of this `chromesthesia2` package with all of the text within the `Chromesthesia` program of the `chromestisia1` package.
2. Within the `chromesthesia2` package of your `CS1` project, establish as a *Java Class* called `Pitch`. Replace all of the text within the `Pitch` program of the `chromesthesia2` package with all of the text within the `Pitch` program of the `chromestisia1` package.
3. Edit in the few obvious places. Run the `Chromesthesia` program of the `chromesthesia2` package, and check it out to make sure that it works just like the `Chromesthesia` program of the `chromesthesia1` package. If it does, good. If not, fix things so that it does. Once everything is in order, you are in a position to carry on with the development of the program within the `chromesthesia2` package.

4. Change the program so that the pitch class to color mapping is as follows:
   - A $\longrightarrow$ new Color(0,0,255)
   - B $\longrightarrow$ new Color(0,255,0)
   - C $\longrightarrow$ new Color(127,0,127)
   - D $\longrightarrow$ new Color(255,255,0)
   - E $\longrightarrow$ new Color(255,0,0)
   - F $\longrightarrow$ new Color(255,127,0)
   - G $\longrightarrow$ new Color(0,255,255)
5. Run the program, and give it a thorough testing.
6. Arrange for the `play` method of the `Pitch` class to function with any of the following three instances of the parameter: `"1"` or `"2"` or `"1/2"`. Do this by refining the following suggestive code:

```
public void play(String d) {
    painter.setColor(color);
    painter.paint(box);
    painter.setColor(randomColor());
    painter.draw(box);
    if ( the duration string equals "1" ) {
        simply play the note
    } else if ( the duration string equals "2" ) {
        double the duration of the note; play it; halve the duration
    } else if ( the duration string equals "1/2" ) {
        halve the duration of the note; play it; double the duration
    }
}
```

7. In the `Chromesthesia` program, change the `playMelody` method to the following code:

```
private static void playMelody(String input, Pitch[] pitches) throws Exception {
    Scanner scanner = new Scanner(input);
    while ( scanner.hasNext() ) {
        String token = scanner.next();
        String pitchName;
        String duration = "";
        if ( token.indexOf(",") < 0 ) {
            pitchName = token.substring(0,1);
            duration = token.substring(1);
        } else {
            pitchName = token.substring(0,2);
            duration = token.substring(2);
        }
        if ( duration.length() == 0 ) { duration = "1"; }
        Pitch pitch = find(pitchName,pitches);
        pitch.play(duration);
    }
}
```

8. Stash the following lines of ABC code in your ABC code stash, and make use of the to give your program a relatively thorough testing.
   (a) `C2 C1 C C1/2 C1/2 E2 E1 E E1/2 E1/2 G2 G1 G G1/2 G1/2`
   (b) `D,2 D,1 D, D,1/2 D,1/2 F,2 F,1 F, F,1/2 F,1/2 A,2 A,1 A, A,1/2 A,1/2`
   (c) `b2 b1 b b1/2 b1/2 b1/2 b1/2 b b1 b2`
9. Extend the duration functionality so that it properly works for: `"3"` and `"1/3"` AND `"2/3"`.

10. Stash the following lines of ABC code in your ABC code stash, and run your program on each one.
    (a) `C,1/3 C,1/3 C,1/3 C, C,3 C1/3 C1/3 C1/3 C C3 c1/3 c1/3 c1/3 c c3`
    (b) `C,2/3 C,1/3 D,2/3 D,1/3 C,2/3 C,1/3 D,2/3 D,1/3 C,2/3 C,1/3 D,1 D,1 D,1 C,3`
11. Add one more command to the set of commands that the interpreter can process. This will be the `AGAIN` command. When you issue it, the most recently entered melodic sequence will be played again. This one is for you to design and implement!
12. Run your program, to make sure it is working properly with `AGAIN`.
13. Stash a couple more ABC encoded sequences in your ABC code stash, doing your best to make them interesting, and also to make good use of the note rendering functionality. Play each of them a couple of times and observe.

Task 4: Post your work

Please post your work for this lab on you Web site. Post the source code for the main `Chromesthesia` program and the `Pitch` class, post an image of the *input box*, and post an image of the *canvas* when a note is being played.

Task 5: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

The Code

This program is comprised of two files, a `Java Main Class` file called `Chromesthesia` and a `Java Class` file called `Pitch`. Both are placed in a packaged called `chromesthesia0`, in anticipation of subsequent versions of the program being placed in other packages.

The Java Main Class `Chromesthesia` program

```
/*
 * This program interprets melodic lines given in ABC notation as a
 * chromesthete might.
 *
 * A Pitch class will be defined, and will take center stage in the
 * processing.
 *
 * Interpreting a melody in ABC notation will amount to flashing
 * colored rectangles for prescribed durations, while sounding
 * the pitch! The color of the rectangle will correspond to pitch
 * class. The duration will correspond to the duration of the note.
 *
 * For this first version of the program, the duration will be held
 * constant at 1 beat.
```

```
 *
 * Three sorts of images will appear on the screen, the chromesthetic
 * output box, a text input box, and an error message box. Simplicity
 * of design is rendered by permitting only one box to be on the screen
 * at a time.
 *
 * ABC represents notes in a manner consistent with these examples:
 * C, D, E, C D E c d e
 *
 * Google ABC music representation if you would like to know more about it.
 */

package chromesthesia0;

import java.util.Scanner;
import javax.swing.JOptionPane;
import javax.swing.SwingUtilities;
import painter.SPainter;

public class Chromesthesia {

    // INFRASTRUCTURE FOR THE PROGRAM -- LAUNCHING A "GRAPHICS" THREAD

    public static void main(String[] args) {
        SwingUtilities.invokeLater(new ThreadForGUI());
    }

    private static class ThreadForGUI implements Runnable {
       @Override
       public void run() {
           new Chromesthesia();
       }
    }

    public Chromesthesia() {
        interpreter();
    }

    // FEATURED VARIABLES

    private static SPainter miro;
    private static Pitch[] pitches;

    // THE INTERPRETER

    public static void interpreter() {

        initialization(); // miro and pitches

        while ( true ) {
            String input = getInput();
            if ( input.equalsIgnoreCase("EXIT") ) {
                break;
            } else {
```

```
            try {
                playMelody(input,pitches);
            } catch (Exception ex) {
                showErrorMessage(ex.toString());
            }
        }
    }

    cleanup(); // miro has to go

}

// METHODS PERTAINING TO THE CHROMESTHETIC PITCHES

private static Pitch[] establishPitches(SPainter painter) {
    Pitch[] pitches = new Pitch[9];
    Pitch pitchMiddleC = new Pitch("C",painter);
    pitches[0] = pitchMiddleC;
    Pitch pitchLowC = new Pitch("C,",painter);
    pitches[1] = pitchLowC;
    Pitch pitchHighC = new Pitch("c",painter);
    pitches[2] = pitchHighC;
    Pitch pitchMiddleD = new Pitch("D",painter);
    pitches[3] = pitchMiddleD;
    Pitch pitchLowD = new Pitch("D,",painter);
    pitches[4] = pitchLowD;
    Pitch pitchHighD = new Pitch("d",painter);
    pitches[5] = pitchHighD;
    Pitch pitchMiddleE = new Pitch("E",painter);
    pitches[6] = pitchMiddleE;
    Pitch pitchLowE = new Pitch("E,",painter);
    pitches[7] = pitchLowE;
    Pitch pitchHighE = new Pitch("e",painter);
    pitches[8] = pitchHighE;
    return pitches;
}

private static Pitch find(String token, Pitch[] pitches) throws Exception {
    for ( int i = 0; i < pitches.length; i = i + 1 ) {
        Pitch pitch = pitches[i];
        if ( pitch.abcName().equals(token) ) {
            return pitch;
        }
    }
    throw new Exception("### PITCH " + token + " NOT FOUND");
}

private static void display(Pitch[] pitches) {
    for ( int i = 0; i < pitches.length; i = i + 1 ) {
        System.out.println(pitches[i].toString());
    }
}

private static void playMelody(String input, Pitch[] pitches) throws Exception {
```

```
        Scanner scanner = new Scanner(input);
        while ( scanner.hasNext() ) {
            String token = scanner.next();
            Pitch pitch = find(token,pitches);
            pitch.play("1");
        }
    }

    // INITIALIZATION, CLEANUP, GETTING INPUT, ERROR MESSAGING

    static private void showErrorMessage(String message) {
        miro.setVisible(false);
        JOptionPane.showMessageDialog(null, message);
    }

    private static void initialization() {
        // ESTABLISH THE PAINTER AND GIVE IT A SUBSTANTIAL BRUSH WIDTH
        miro = new SPainter("Chromesthesia",500,500);
        miro.setVisible(false);
        miro.setBrushWidth(7);
        // ESTABLISH THE CHROMESTITIC PITCH CLASS OBJECTS
        pitches = establishPitches(miro);
        display(pitches);
    }

    private static String getInput() {
        miro.setVisible(false);
        String label = "Please enter a melody in ABC notation, or EXIT ...     ";
        String input = JOptionPane.showInputDialog(null,label);
        miro.setVisible(true);
        if ( input == null ) { input = ""; }
        return input;
    }

    static private void cleanup() {
        System.exit(0);
    }

}
```

The Java Class `Pitch` program

```
/*
 * The Pitch class models the pitch of a note in a manner that will facilitate
 * the chromesthetic processing of the pitch. A Pitch object will have five
 * properties:
 * - String name | ABC notation pitch name
 * - SPainter painter | the painting agent
 * - Note note | a note that will be set to the pitch corresponding to the
 *   ABC notation pitch name
 * - SRectangle box | an SRectangle object that will chromesthetically
 *   represent the pitch
```

```
 * - Color color | the color associated with the pitch for the presumed
 *   chromesthete
 */

package chromesthesia0;

import java.awt.Color;
import note.SNote;
import painter.SPainter;
import shapes.SRectangle;

public class Pitch {

    // INSTANCE VARIABLES
    private String abcName;
    private SPainter painter;
    private SRectangle box;
    private SNote note;
    private Color color;

    public Pitch(String abcName, SPainter painter) {
        this.abcName = abcName;
        this.painter = painter;
        this.box = new SRectangle(painter.painterHeight-50,painter.painterWidth-50);
        this.note = createNoteForThisPitch(abcName);
        this.color = getPitchClassColor(abcName.substring(0,1).toUpperCase());
    }

    public String toString() {
        return "[ " + abcName + " | " + note.degree() + " | " + color + " ]";
    }

    public String abcName() {
        return abcName;
    }

    private SNote createNoteForThisPitch(String abcPitchClassName) {
        SNote note = new SNote();
        if ( abcPitchClassName.equals("C") ) {
          // nothing to do
        } else if ( abcPitchClassName.equals("C,") ) {
            note.lp(7);
        } else if ( abcPitchClassName.equals("c") ) {
            note.rp(7);
        } else if ( abcPitchClassName.equals("D") ) {
            note.rp(1);
        } else if ( abcPitchClassName.equals("D,") ) {
            note.lp(6);
        } else if ( abcPitchClassName.equals("d") ) {
            note.rp(8);
        } else if ( abcPitchClassName.equals("E") ) {
            note.rp(2);
        } else if ( abcPitchClassName.equals("E,") ) {
            note.lp(5);
```

```
        } else if ( abcPitchClassName.equals("e") ) {
            note.rp(9);
        }
        return note;
    }

    private Color getPitchClassColor(String letter) {
        if ( letter.equals("C") ) {
            return Color.BLUE;
        } else if ( letter.equals("D") ) {
            return Color.GREEN;
        } else if ( letter.equals("E") ) {
            return new Color(127,0,127);
        } else {
            return Color.BLACK;
        }
    }

    public void play(String d) {
        painter.setColor(color);
        painter.paint(box);
        painter.setColor(randomColor());
        painter.draw(box);
        if ( d.equals("1") ) {
            note.play();
        }
    }

    private static Color randomColor() {
        int rv = (int)(Math.random()*256);
        int gv = (int)(Math.random()*256);
        int bv = (int)(Math.random()*256);
        return new Color(rv,gv,bv);
    }

}
```

29 Presentation: L-Systems and Fractals

This material is presented in real time during the course lectures.

30 Lab 14: Fun with Fractals

A. Hertzfeld on PROGRAMMING

It's [programming] the only job I can think of where I get to be both an engineer and an artist. There's an incredible, rigorous, technical element to it, which I like because you have to do very precise thinking. On the other hand, it has a wildly creative side where the boundaries of imagination are the only real limitation.

H. Morowitz on COMPUTER SCIENCE AND BIOLOGY

Computer science is to biology what calculus is to physics. It's the natural mathematical technique that best maps the character of the subject.

Overview

A brief introduction to L-Systems will be presented. Then, in the spirit of implementing something of *algorithmic* consequence with an *interdisciplinary* flavor (linguistics and biology), a class which represents *L-Systems* will be detailed. This class will serve as the basis of programs to perform some *algorithmic composition*, and to draw some now classic images, which are rendered according to intriguing mathematical sets. The algorithmic composition makes good use of *abstract classes*. The set rendering relies on *Turtle Geometry*.

Why do it?

As you work through this lab you will:

1. Incorporate *abstract classes* into your programming.
2. Program a *generative algorithm*.
3. Play with *L-Systems* and *fractals*.
4. Render L-System strings graphically by means of *Turtle Geometry*.
5. Render L-System strings sonically to perform some *algorithmic composition*
6. Focus on the *Javadoc* mechanism for describing programs.

Task 1: Prepare to do the Java programming for this lab in IntelliJ

Continue to work in the CS1 project. But anticipate this lab to take some time! It is not designed to be completed in the lab, or even within the scope of the semester. This one is for all those who would like to do something of some significance in anticipation of subsequent study within the realm of computer programming. Part of your preparation for this lab should be adopting a mindset in which you plan to work on gaining independence with respect to computer programming, and autonomy with respect to crafting goals within a well-defined domain, in this case the

application of L-systems to the arts.

Task 2: Get acquainted with L-Systems

The Wiki page for L-systems is really quite good. You might like to spend some time with it prior to continuing with this lab. That said, all you really need to know about L-Systems is what they are, and that they have application beyond the modeling of algae which inspired biologist Atistid Lindenmayer to invent them.

What is an L-System?

An **L-System**, or **Lindenmayer system**, is a *parallel rewriting system* involving the following three components:

1. an *alphabet* (set of symbols)
2. an *axiom* (string of symbols)
3. a *production* for each alphabet symbol that maps the symbol into a list of symbols

An L-System can also be viewed as a *formal grammar*, a formalism that defines a set of strings of symbols. If you happen to be familiar with the much more well-known *context free grammar*, you can take delight in the fact that L-Systems are very different in a number of significant respects!

Algae

For example, here is the *Algae* L-System, together with the first few generations of the system:

The Algae System:

1. Alphabet: {A,B}
2. Axiom: A
3. Productions:
   (a) A → A B
   (b) B → A

The first several generations, each of which, other than the first, which is just the axiom, are derived from its predecessor simply by replacing *each* symbol by the string it produces according to its production.

- A
- A B
- A B A
- A B A A B
- A B A A B A B A
- A B A A B A B A A B A A B

Cantor Dust

As a second example, here is the *Cantor Dust* L-System, together with the first few generations of the system:

The Cantor Dust System:

1. Alphabet: {A,B}
2. Axiom: A
3. Productions:
   (a) A → A B A
   (b) B → B B B

The first several generations:

- A
- A B A
- A B A B B B A B A
- A B A B B B A B A B B B B B B B B A B A B B B A B A

Sierpinski Triangle

And as a third example, here is the *Sierpinski Triangle* L-System, together with the first few generations of the system:

The Sierpinski Triangle System:

1. Alphabet: {F,G,-,+}
2. Axiom: F - G - G
3. Productions:
   (a) F → F - G + F + G - F
   (b) G → G G
   (c) - → -
   (d) + → +

The first several generations:

- F - G - G
- F - G + F + G - F - G G - G G
- F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G - G G G G
- F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G + F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F + G G G G - F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G G G G G - G G G G G G G G

Task 3: Create the `LSystem` Java Class file and the `Production` Java Class file

Within a package called `lsystem`, establish two classes, both Java Class files, the first called `LSystem` to represent L-Systems, and the second called `Production` to represent the productions of the L-Systems. The code for both

classes is presented here. For now, simply study the code, and type it in to the appropriately named Java Class files. You will have an opportunity to test the code shortly.

The `LSystem` Java Class File

```
/*
 * General LSystem class, which will be the super class to particular LSystem
 * classes. It represents an LSystem in terms of its name, its axiom, and its
 * production set.
 */

package lsystem;

import java.util.LinkedList;
import java.util.List;
import java.util.Scanner;

public class LSystem {

    // Instance variables. The axiom and productions are protected so that
    // they can be directly referenced from subclasses. It will be up to
    // the subclasses to fully instantiate the L-Systems by instantiating
    // their axiom and productions instance variables.

    private String name;
    protected String axiom;
    protected List<Production> productions;

    /**
     * Create an LSystem by giving it just its name. In the constructor of
     * the subclass the axiom and the productions will be provided.
     * @param name is the name of the L-System
     */
    public LSystem(String name) {
        this.name = name;
    }

    /**
     * Compute a textual representation of the L-System.
     * @return the textual representation of the L-System
     */
    public String toString() {
        return "Name = " + name + "\n" +
               "Axiom = " + axiom + "\n" +
               "Productions ...\n" + textRepresentation(productions);
    }

    private String textRepresentation(List<Production> productions) {
        String text = "";
        for ( Production p : productions ) {
            text = text + p.toString() + "\n";
```

```
    }
    return text;
}

/**
 * Compute the generation of the L-System indicated by the given value.
 * @param generationNumber indicates the generation to be produced
 * @return the generation of the L-System indicated by the parameter
 */
protected String generation(int generationNumber) {
    LinkedList<String> generations = new LinkedList<String>();
    String generation = axiom;
    generations.add(generation);
    for ( int i = 1; i <= generationNumber; i++ ) {
        generation = next(generation);
        generations.add(generation);
    }
    return generations.getLast();
}

/**
 * Produce/display some desired number of generations of the L-System.
 * The user is asked for the number.
 */
protected void generate() {
    System.out.print("How many generations? ");
    Scanner scanner = new Scanner(System.in);
    int nrOfGenerations = scanner.nextInt();
    LinkedList<String> generations = new LinkedList<String>();
    String generation = axiom;
    System.out.println("generation 0 = " + generation);
    generations.add(generation);
    for ( int i = 1; i <= nrOfGenerations; i++ ) {
        generation = next(generation);
        generations.add(generation);
        System.out.println("generation " + i + " = " + generation);
    }
}

private String next(String generation) {
    String result = "";
    Scanner scanner = new Scanner(generation);
    while ( scanner.hasNext() ) {
        String symbol = scanner.next();
        Production production = find(symbol,productions);
        result = result + production.sequence() + " ";
    }
    return result.trim();
}

private Production find(String symbol, List<Production> productions) {
    for ( Production production : productions ) {
        if ( production.symbol().equalsIgnoreCase(symbol) ) {
            return production;
```

```
            }
        }
        return null;
    }

}
```

The `Production` Java Class File

```
/*
 * This class is used by the LSystem class in order to help represent the
 * productions of the system. It stores the left hand side of the production
 * as a symbol and the right hand side as a sequence of symbols, representing
 * everything in terms of character strings.
 */

package lsystem;

public class Production {

    // Instance varibales: the left hand side and the right hand side of the
    // production.

    private String symbol;
    private String sequence;

    /**
     * Create an LSystem production by providing its left hand side and its
     * right hand side.
     * @param symbol is the left hand side of the production
     * @param sequence is the right hand side of the production
     */
    public Production(String symbol, String sequence) {
        this.symbol = symbol;
        this.sequence = sequence;
    }

    /**
     * Referencer for the left hand side of the production.
     * @return the left hand side of the production
     */
    public String symbol() {
        return symbol;
    }

    /**
     * Referencer for the right hand side of the production.
     * @return the right hand side of the production
     */
    public String sequence() {
        return sequence;
```

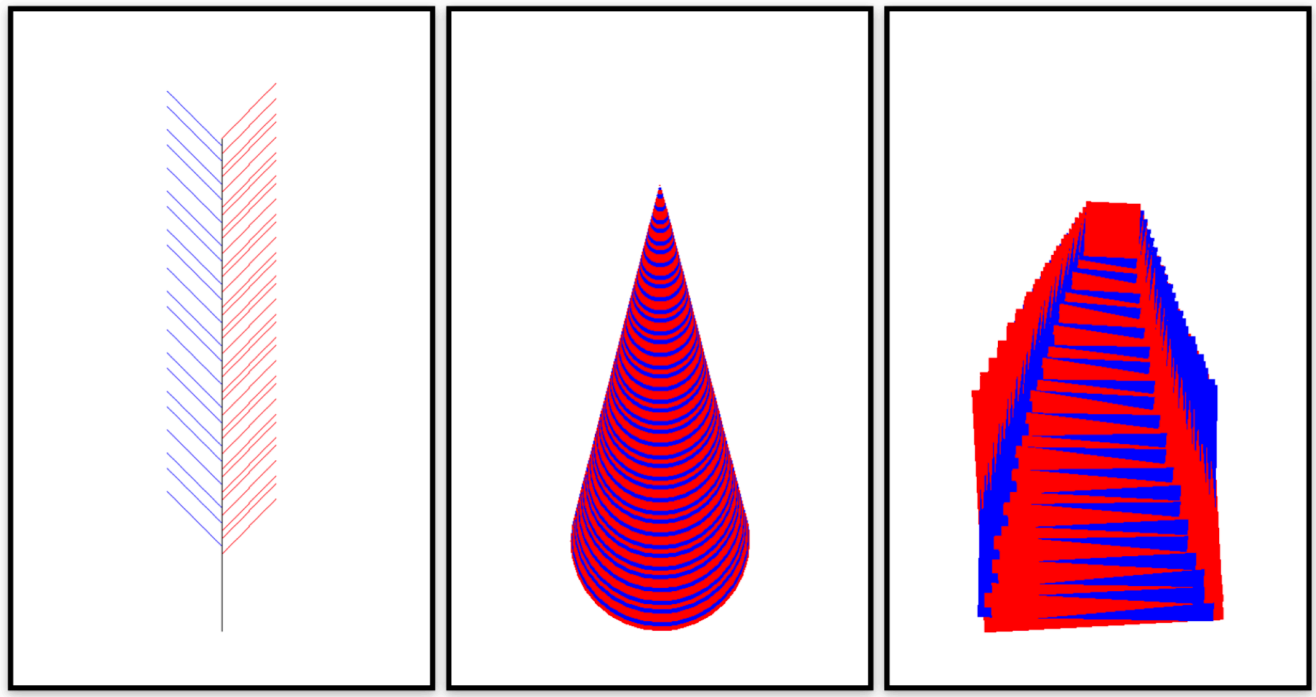
```
    }

    /**
     * Compute a simple textual representation of the L-System production.
     * @return the textual representation of the production
     */
    public String toString() {
        return symbol + " --> " + sequence;
    }
}
```

Task 4: Demo of the `AlgaePainter` Java Main Class file

The images displayed below are renderings of *Algae strings* produced by the `AlgaePainter` program. A demo of the run of the program that produced the images is presented so that you will have an opportunity to think on the behavior of the program, which takes the form of an interpreter, prior to establishing it, running it, varying its specialized painters, and running it some more. Please just enjoy a quick look at the images and study the demo in preparation for the next several tasks.

Images Generated by `AlgaePainter`



Standard IO demo of `AlgaePainter`

```
run:
Algae>>> help
HELP - display this help menu to the standard output stream
DISPLAY - display the Algae L-System, vocabulary and axiom and productions
GENERATE - generate some number of generations, as specified by the user
PAINT - paint a rendering of some generation of the Algae system
DISPOSE - get rid of the canvas on which the rendering was painted
EXIT - terminate execution of this program
Algae>>> display
Name = Algae
Axiom = A
Productions ...
A --> A B
B --> A
Algae>>> generate
How many generations? 6
generation 0 = A
generation 1 = A B
generation 2 = A B A
generation 3 = A B A A B
generation 4 = A B A A B A B A
generation 5 = A B A A B A B A A B A A B
generation 6 = A B A A B A B A A B A A B A B A A B A B A
Algae>>> paint
Which player (ALines or ACircles or ASquares)? ALines
Generation number? 8
Algae>>> dispose
Algae>>> paint
Which player (ALines or ACircles or ASquares)? ACircles
Generation number? 10
Algae>>> dispose
Algae>>> paint
Which player (ALines or ACircles or ASquares)? ASquares
Generation number? 8
Algae>>> dispose
Algae>>> exit
BUILD SUCCESSFUL (total time: 3 minutes 54 seconds)
```

Task 5: Create some *painters* to render some Algae System images

Establish four Java Class files in a package called `painters`. First establish an *abstract class* which contains the basic logic for rendering strings of As and Bs. All this class lacks is any notion of what it means to render A or B. Then establish three different classes which *inherit* the functionality of the abstract class, and which complete the abstract class by defining just what it means to render an A and to render a B. For now, simply study the code, and then enter the code for each of the four classes (the abstract class and the three refinements). Soon enough you will have an opportunity to test the code.

The abstract ABPainter Java Class file

```
/*
 * This abstract class serves to render images based on strings of As and Bs.
 * The renderer is coded in such a way that the rendering of each symbol is
 * left left unspecified. To complete the renderer, the methods thingA and
 * thingB must be specified. That is the job of the classes which extend this
 * abstract class.
 */

package painters;

import java.awt.Color;
import painter.SPainter;
import java.util.Scanner;

public abstract class ABPainter {

    // The simple painter, with its canvas and everything else, is the sole
    // instance variable for this class.

    protected SPainter painter;

    /**
     * Create an ABPainter, a painter which bases its work on strings of As and
     * Bs. It is basically a simple painter (SPainter) which processes the As
     * and the Bs in the string, one at a time, by somehow graphically rendering
     * them.
     * @param p is the work horse painter
     */
    public ABPainter(SPainter p) {
        painter = p;
        painter.setScreenLocation(25,25);
        painter.toFront();
        painter.setVisible(true);
        painter.setColor(Color.BLACK);
    }

    /**
     * Paint an image by processing the given string of A and B symbols.
     * @param line is a string of As and Bs, presumably generated by some
     * L-System
     */
    public void paint(String line) {
        Scanner symbolString = new Scanner(line);
        while ( symbolString.hasNext() ) {
            String symbol = symbolString.next();
            if ( symbol.equals("A") ) {
                thingA();
            } else if ( symbol.equals("B") ) {
                thingB();
            }
```

```
        }
    }

    /**
     * Reference to an encoding of what it means to render the A symbol
     * graphically.
     */
    public abstract void thingA();

    /**
     * Reference to an encoding of what it means to render the A symbol
     * graphically.
     */
    public abstract void thingB();

}
```

The ABPainterALines Java Class file

```
/*
 * Subclass of the abstract ABPainter class which renders line images that
 * look something like ferns, something like trees, in terms of the symbols
 * A and B.
 */

package painters;

import java.awt.Color;
import painter.SPainter;

public class ABPainterALines extends ABPainter {

    /**
     * Create a specialization of an ABPainter which renders odd looking
     * fern like tree structures with red and blue limbs.
     * @param painter is the work horse painter
     */
    public ABPainterALines(SPainter painter) {
        super(painter);
        painter.mbk(165);
    }

    static private double distance = 90;
    static private int delta = 45;

    /**
     * Draw a red branch, to the right, off of a bit of black trunk.
     */
    public void thingA() {
        painter.dfd(distance);
        painter.tr(delta);
```

```
        painter.setColor(Color.RED);
        painter.dfd(distance);
        painter.setColor(Color.BLACK);
        painter.mbk(distance);
        painter.tl(delta);
        painter.mbk(distance);
        painter.mfd(distance/10);
    }

    /**
     * Draw a blue branch, to the left, off of a bit of black trunk.
     */
    public void thingB() {
        painter.dfd(distance);
        painter.tl(delta);
        painter.setColor(Color.BLUE);
        painter.dfd(distance);
        painter.setColor(Color.BLACK);
        painter.mbk(distance);
        painter.tr(delta);
        painter.mbk(distance);
        painter.mfd(distance/10);
    }

}
```

The ABPainterACircles Java Class file

```
/*
 * Subclass of the abstract ABPainter class which renders "dots images" that
 * look something like cones in terms of the symbols A and B.
 */

package painters;

import java.awt.Color;
import java.util.Random;
import painter.SPainter;
import shapes.SCircle;

public class ABPainterACircles extends ABPainter {

    /**
     * Create a specialization of an ABPainter which renders odd looking
     * cone-like structures in red and blue.
     * @param painter is the work horse painter
     */
    public ABPainterACircles(SPainter painter) {
        super(painter);
        painter.mbk(60);
    }
```

```
    static private double distance = 4;
    static private int delta = 1;
    static private Random random = new Random();
    static private SCircle dot = new SCircle(160);

    /**
     * Draw a red dot, adjust the position of the painter, and shrink the dot.
     */
    public void thingA() {
        painter.setColor(Color.RED);
        painter.paint(dot);
        painter.mfd(distance);
        dot.shrink(delta);
    }

    /**
     * Draw a blue dot, adjust the position of the painter, and shrink the dot.
     */
    public void thingB() {
        painter.setColor(Color.BLUE);
        painter.paint(dot);
        painter.mfd(distance);
        dot.shrink(delta);
    }

}
```

The ABPainterASquares Java Class file

```
/*
 * Subclass of the abstract ABPainter class which renders images based on
 * squares that look something like melting towers in terms of the symbols
 * A and B.
 */

package painters;

import java.awt.Color;
import java.util.Random;
import painter.SPainter;
import shapes.SSquare;

public class ABPainterASquares extends ABPainter {

    /**
     * Create a specialization of an ABPainter which renders odd looking
     * tower-like structures in red and blue.
     * @param painter is the work horse painter
     */
    public ABPainterASquares(SPainter painter) {
```

```
        super(painter);
        painter.mbk(20);
        painter.tl(3);
    }

    static private double distance = 6;
    static private int delta = 4;
    static private Random random = new Random();
    SSquare square = new SSquare(280);

    /**
     * Draw a red square, adjust the position of the painter, and shrink the
     * the square, and alter the heading of the painter just a bit.
     */
    public void thingA() {
        painter.setColor(Color.RED);
        painter.paint(square);
        painter.mfd(distance);
        square.shrink(delta);
        painter.tr(4);
    }

    /**
     * Draw a blue square, adjust the position of the painter, and shrink the
     * the square, and alter the heading of the painter just a bit.
     */
    public void thingB() {
        painter.setColor(Color.BLUE);
        painter.paint(square);
        painter.mfd(distance);
        square.shrink(delta);
        painter.tl(6);
    }

}
```

Task 6: Establishment of the `AlgaePainter` Java Main Class file

The following program makes use of the refinements of the `ABPainter` class in order to draw images based on the Algae strings. It conditionally determines which Algae string to render, and which of the three renderers thus far established to employ. Study it. Then enter it.

The `AlgaePainter` Java Class file

```
/*
 * This program can generate and process generations of the Algae L-System,
 * where processing amounts to performing graphical renderings of the strings
 * of symbols A and B of the system. The program takes the form of an interpreter.
 * See the comment prefacing the constructor for additional details.
```

```
 */

package lsystem;

import java.util.ArrayList;
import java.util.List;
import java.util.Scanner;
import javax.swing.SwingUtilities;
import painter.SPainter;
import painters.ABPainter;
import painters.ABPainterACircles;
import painters.ABPainterALines;
import painters.ABPainterASquares;

public class AlgaePainter extends LSystem {

    /**
     * Create an AlgaePainter object, which is so tightly coupled to its
     * behavior as an interpreter that its private interpreter method is
     * called from this constructor. The program can represent the Algae
     * L-System, and can derive successive generations of strings within
     * the system. Specifically, the interpreter can process the following
     * commands: <br>
     * *  HELP - display this help menu to the standard output stream<br>
     * *  DISPLAY - display the Algae L-System, vocabulary and axiom and productions<br>
     * *  GENERATE - generate some number of generations, as specified by the user<br>
     * *  PAINT - paint a rendering of some generation of the Algae system<br>
     * *  DISPOSE - get rid of the canvas on which the rendering was painted<br>
     * *  EXIT - terminate execution of this program<br>
     * With respect to the painting, a conditional statement determines which
     * of a number of specialized renderers will be used to paint the image.
     * The painter will then do its thing to the particular generation of the
     * Algae system that it has to work with.
     */
    public AlgaePainter() {
        super("Algae");
        axiom = "A";
        productions = productions();
        interpreter();
    }

    private List<Production> productions() {
        Production p1 = new Production("A","A B");
        Production p2 = new Production("B","A");
        ArrayList<Production> productions = new ArrayList<>();
        productions.add(p1);
        productions.add(p2);
        return productions;
    }

    private void interpreter() {
        Scanner scanner = new Scanner(System.in);
        System.out.print("Algae>>> ");
        String line = scanner.next();
```

```
    if ( line.equalsIgnoreCase("exit") ) {
        System.exit(0);
    } else if ( line.equalsIgnoreCase("generate") ) {
        generate();
    } else if ( line.equalsIgnoreCase("paint") ) {
        paint();
    } else if ( line.equalsIgnoreCase("dispose") ) {
        miro.end();
    } else if ( line.equalsIgnoreCase("help") ) {
        help();
    } else if ( line.equalsIgnoreCase("display") ) {
        System.out.print(toString());
    } else {
        System.out.println("Sorry, I don't recognize: " + line);
    }
    interpreter();
}

private static void help() {
    System.out.println("HELP - display this help menu to " +
            "the standard output stream");
    System.out.println("DISPLAY - display the Algae L-System, " +
            "vocabulary and axiom and productions");
    System.out.println("GENERATE - generate some number of generations, " +
            "as specified by the user");
    System.out.println("PAINT - paint a rendering of some generation " +
            "of the Algae system");
    System.out.println("DISPOSE - get rid of the canvas " +
            "on which the rendering was painted");
    System.out.println("EXIT - terminate execution of this program");
}

private SPainter miro;

private void paint() {
    Scanner scanner = new Scanner(System.in);
    System.out.print("Which player (ALines or ACircles or ASquares)? ");
    String thePainter = scanner.next();
    System.out.print("Generation number? ");
    int generationNumber = scanner.nextInt();
    miro = new SPainter(500,800);
    ABPainter painter = new ABPainterALines(miro);  // arbitrary
    if ( thePainter.equalsIgnoreCase("ALines") ) {
        painter = new ABPainterALines(miro);
    } else if ( thePainter.equalsIgnoreCase("ACircles") ) {
        painter = new ABPainterACircles(miro);
    } else if ( thePainter.equalsIgnoreCase("ASquares") ) {
        painter = new ABPainterASquares(miro);
    }
    painter.paint(generation(generationNumber));
}

/**
 * Simply sets up the infrastructure for the program, and gets things started.
```

```
    */
    public static void main(String[] args) {
      SwingUtilities.invokeLater(new Runnable() {
         public void run() {
            new AlgaePainter();
         }
      });
    }

}
```

Task 7: Replicate the `AlgaePainter` demo

By now, you should have established, in your world, all of the code needed to replicate the demo of the `AlgaePainter` that was previously presented. Run the `AlgaePainter` program and replicate the demo!

Task 8: Change the *painters* and generate another `AlgaePainter` demo

By analogy with `ABPainterALines`, `ABPainterACircles`, and `ABPainterASquares`, write corresponding Java classes `ABPainterALines2`, `ABPainterACircles2`, and `ABPainterASquares2` which will generate three images when the programs are run which are interestingly different from those generated by the given programs. Simply study the three given programs, and then write three alternates. Run the `AlgaePainter` program and interact with it to generate a demo quite like that which was previously presented – but which produces different images!

Task 9: Algae System music - discussion and demos

You can render a strings of As and Bs sonically as well as visually. For example, you could bind A and B to a couple of the simple composer's basic sequences, or to a couple of the simple composer's locomotive sequences, or to a couple sequences in of the simple composer's collection of Bach minuet fragments. Rather than rendering A and B visually with the simple painter, this program renders them sonically with the simple composer.

Three sound files were generated when the program `AlgaePlayer`, to be presented, was run in the manner shown in the following demo. If you would like to hear them before proceeding to implement the program, you will find them on the Web site associated with this text under the names `BasicAlgaeSequence1.mp3`, `LocomotiveAlgaeSequence1.mp3`, and `BachAlgaeSequence1.mp3`.

Please don't be expecting anything particularly good from a musical point of view. Rather, expect something suggestive of the sort of thing that is involved in algorithmic composition. To hear something good from a tonal music perspective, requires very different algorithms grounded in theories of human perception and traditions of western music. Still, this program does illustrate the basic idea behind algorithmic composition. Find an algorithm, render a sonic stream in a manner consistent with the algorithm, quite likely by means of other algorithms. In this case, the basic algorithm is an L-System generator, and the sole additional algorithmic infusion merely arranges for stepwise motion of the sequences to which the vocabulary symbols (A and B) produce.

Standard IO demo of `AlgaePlayer`

```
run:
Algae>>> help
HELP - display this help menu to the standard output stream
DISPLAY - display the Algae L-System, vocabulary and axiom and productions
GENERATE - generate some number of generations, as specified by the user
PLAY - paint a sonic rendering of some generation of the Algae system
DISPOSE - get rid of the canvas on which the rendering was painted
EXIT - terminate execution of this program
Algae>>> display
Name = Algae
Axiom = A
Productions ...
A --> A B
B --> A
Algae>>> generate
How many generations? 5
generation 0 = A
generation 1 = A B
generation 2 = A B A
generation 3 = A B A A B
generation 4 = A B A A B A B A
generation 5 = A B A A B A B A A B A A B
Algae>>> play
Which player (Bach1 or Locomotion1 or Basics1)? Basics1
Generation number? 5
line = A B A A B A B A A B A A B
Stepwise motion = LRLRLRRRLLRL
(C,1/2) \ (B,1/2) / (C,1)
\ (B,1/2) (B,1/2) (B,1/2) (B,1/2)
/ (C,1/2) \ (B,1/2) / (C,1)
\ (B,1/2) \ (A,1/2) / (B,1)
/ (C,1/2) (C,1/2) (C,1/2) (C,1/2)
\ (B,1/2) \ (A,1/2) / (B,1)
/ (C,1/2) (C,1/2) (C,1/2) (C,1/2)
/ (D,1/2) \ (C,1/2) / (D,1)
/ (E,1/2) \ (D,1/2) / (E,1)
\ (D,1/2) (D,1/2) (D,1/2) (D,1/2)
\ (C,1/2) \ (B,1/2) / (C,1)
/ (D,1/2) \ (C,1/2) / (D,1)
\ (C,1/2) (C,1/2) (C,1/2) (C,1/2)
(C,3)
Score file name, without extension, from /Users/blue/ directory?  CS1Files/midi/Basics1
Score saved as file /Users/blue/CS1Files/midi/Basics1.midi
Algae>>> play
Which player (Bach1 or Locomotion1 or Basics1)? Locomotion1
Generation number? 5
line = A B A A B A B A A B A A B
Stepwise motion = RLRLLLRLRRLR
(C,3/4) / (D,1/4) / (E,3/4) / (F,1/4) \ (E,3/4) \ (D,1/4) \ (C,1)
/ (A,1/2) \ (G,1/2) \ (F,1/2) \ (E,1/2) \ (D,2)
```

```
\ (C,3/4) / (D,1/4) / (E,3/4) / (F,1/4) \ (E,3/4) \ (D,1/4) \ (C,1)
/ (D,3/4) / (E,1/4) / (F,3/4) / (G,1/4) \ (F,3/4) \ (E,1/4) \ (D,1)
/ (G,1/2) \ (F,1/2) \ (E,1/2) \ (D,1/2) \ (C,2)
\ (B,3/4) / (C,1/4) / (D,3/4) / (E,1/4) \ (D,3/4) \ (C,1/4) \ (B,1)
/ (E,1/2) \ (D,1/2) \ (C,1/2) \ (B,1/2) \ (A,2)
/ (B,3/4) / (C,1/4) / (D,3/4) / (E,1/4) \ (D,3/4) \ (C,1/4) \ (B,1)
\ (A,3/4) / (B,1/4) / (C,3/4) / (D,1/4) \ (C,3/4) \ (B,1/4) \ (A,1)
/ (F,1/2) \ (E,1/2) \ (D,1/2) \ (C,1/2) \ (B,2)
/ (C,3/4) / (D,1/4) / (E,3/4) / (F,1/4) \ (E,3/4) \ (D,1/4) \ (C,1)
\ (B,3/4) / (C,1/4) / (D,3/4) / (E,1/4) \ (D,3/4) \ (C,1/4) \ (B,1)
/ (G,1/2) \ (F,1/2) \ (E,1/2) \ (D,1/2) \ (C,2)
(C,3)
Score file name, without extension, from /Users/blue/ directory?  CS1Files/midi/Locomotion1
Score saved as file /Users/blue/CS1Files/midi/Locomotion1.midi
Algae>>> play
Which player (Bach1 or Locomotion1 or Basics1)? Bach1
Generation number? 5
line = A B A A B A B A A B A A B
Stepwise motion = LRRLRLLRRRLL
(C,1) \ (F,1/2) / (G,1/2) / (A,1/2) / (B,1/2)
(B,1) / (F,1/2) \ (E,1/2) / (F,1)
\ (C,1) \ (F,1/2) / (G,1/2) / (A,1/2) / (B,1/2)
/ (D,1) \ (G,1/2) / (A,1/2) / (B,1/2) / (C,1/2)
(C,1) / (G,1/2) \ (F,1/2) / (G,1)
\ (D,1) \ (G,1/2) / (A,1/2) / (B,1/2) / (C,1/2)
(C,1) / (G,1/2) \ (F,1/2) / (G,1)
\ (B,1) \ (E,1/2) / (F,1/2) / (G,1/2) / (A,1/2)
/ (C,1) \ (F,1/2) / (G,1/2) / (A,1/2) / (B,1/2)
/ (D,1) / (A,1/2) \ (G,1/2) / (A,1)
\ (E,1) \ (A,1/2) / (B,1/2) / (C,1/2) / (D,1/2)
(D,1) \ (G,1/2) / (A,1/2) / (B,1/2) / (C,1/2)
(C,1) / (G,1/2) \ (F,1/2) / (G,1)
\ (C,3)
Score file name, without extention, from /Users/blue/ directory?  CS1Files/midi/Bach1
Score saved as file /Users/blue/CS1Files/midi/Bach1.midi
Algae>>> exit
BUILD SUCCESSFUL (total time: 2 minutes 42 seconds)
```

Task 10: Create some *players* to sonically render some Algae L-System strings

An abstract class is presented which contains the basic logic for rendering strings of As and Bs. All it lacks is any notion of what it means to render and A or a B. Three different classes are then presented which inherit the functionality of the abstract class, but which complete it by saying just what it means to render an A and to render a B. Simply enter the four classes, in appropriately named Java Class files, in a package called `players`.

The abstract ABPlayer Java Class file

```
/*
 * This abstract class serves to render melodies based on strings of As and Bs.
 * The renderer is coded in such a way that the rendering of each symbol is
 * left left unspecified. To complete the renderer, the methods thingA and
 * thingB must be specified. That is the job of the classes which extend this
 * abstract class.
 */

package players;

import composer.SComposer;
import java.util.Random;
import java.util.Scanner;

public abstract class ABPlayer {

    // The simple composer is the sole instance variable for this class.

    protected SComposer composer;

    /**
     * Create an ABPlayer, a performer which bases its work on strings of As and
     * Bs. It is basically a simple composer (SComposer) which processes the As
     * and the Bs in the string, one at a time, by somehow sonically rendering
     * them.
     * @param c is the work horse painter
     */
    public ABPlayer(SComposer c) {
        composer = c;
    }

    /**
     * Play a melody by processing the given string of A and B symbols.
     * @param line is a string of As and Bs, presumably generated by some
     * L-System. But there is a "twist". An "add on" imposes stepwise
     * motion, for the most part, on the melodic fragments to which the
     * A and B are bound.
     */
    public void play(String line) {
        composer.beginScore();
        composer.text();
        String motionLine = motionLine(line) + "S";
        int x = 0;
        Scanner symbolString = new Scanner(line);
        while ( symbolString.hasNext() ) {
            String symbol = symbolString.next();
            if ( symbol.equals("A") ) {
                thingA();
            } else if ( symbol.equals("B") ) {
                thingB();
```

```
        }
        if ( symbolString.hasNext() ) {
            String direction = motionLine.substring(x,x+1);
            changePitch(composer,direction);
            x = x + 1;
        }
    }
    composer.mms_31_JSB_M1();
    composer.untext();
    composer.saveScore();
}

private String motionLine(String line) {
    System.out.println("line = " + line);
    int lineLength = lineLength(line);
    int motionLineLength = lineLength-1;
    String orderedMotionLine = orderedMotionLine(motionLineLength);
    String unorderedMotionLine = unorderedMotionLine(orderedMotionLine);
    System.out.println("Stepwise motion = " + unorderedMotionLine);
    return unorderedMotionLine;
}

private int lineLength(String line) {
    if ( line.equals("") ) {
        return 0;
    } else if ( line.substring(0,1).equals(" ") ) {
        return lineLength(line.substring(1));
    } else {
        return 1 + lineLength(line.substring(1));
    }
}

private String orderedMotionLine(int motionLineLength) {
    if ( motionLineLength == 0 ) {
        return "";
    } else if ( motionLineLength == 1 ) {
        return "S";
    } else {
        return "RL" + orderedMotionLine(motionLineLength-2);
    }
}

private String unorderedMotionLine(String orderedMotionLine) {
    if ( orderedMotionLine.length() < 2 ) {
        return orderedMotionLine;
    } else {
        String element = pick(orderedMotionLine);
        String remainder = remove(element,orderedMotionLine);
        return element + unorderedMotionLine(remainder);
    }
}

private Random generator = new Random();
```

```
    private String pick(String orderedMotionLine) {
        int rn = generator.nextInt(orderedMotionLine.length());
        return orderedMotionLine.substring(rn,rn+1);
    }

    private String remove(String element, String bag) {
        int position = bag.indexOf(element);
        return bag.substring(0,position) + bag.substring(position+1);
    }

    private void changePitch(SComposer composer, String direction) {
        if ( direction.equalsIgnoreCase("R") ) {
            composer.rp();
        } else if ( direction.equalsIgnoreCase("L") ) {
            composer.lp();
        } else if ( direction.equalsIgnoreCase("S") ) {

        }
    }

    /**
     * Reference to an encoding of what it means to render the A symbol
     * sonically.
     */
    public abstract void thingA();

    /**
     * Reference to an encoding of what it means to render the B symbol
     * sonically.
     */
    public abstract void thingB();

}
```

The ABPlayerBasics Java Class file

```
/*
 * Subclass of the abstract ABPlayer class which renders simple melodies by
 * binding A and B each to a simple 4 beat sequence.
 */

package players;

import composer.SComposer;

public class ABPlayerBasics extends ABPlayer {

    /**
     * Create a specialization of an ABPlayer which renders simple melodic
     * melodies by gluing together simple 4 beat fragments.
     * @param composer is the work horse composer
```

```
     */
    public ABPlayerBasics(SComposer composer) {
        super(composer);
    }

    /**
     * Play a simple 4 beat sequence.
     */
    public void thingA() {
        composer.s2(); composer.mms6(); composer.x2();
    }

    /**
     * Play a simple 4 beat sequence.
     */
    public void thingB() {
        composer.s2(); composer.mms3(); composer.x2();
    }

}
```

The ABPlayerLocomotion Java Class file

```
/*
 * Subclass of the abstract ABPlayer class which renders simple melodies by
 * binding A and B each to a simple locomotive sequences.
 */
package players;

import composer.SComposer;

public class ABPlayerLocomotion extends ABPlayer {

    /**
     * Create a specialization of an ABPlayer which renders simple melodic
     * melodies by gluing together simple locomotive fragments.
     * @param composer is the work horse composer
     */
    public ABPlayerLocomotion(SComposer composer) {
        super(composer);
    }

    /**
     * Play a simple 4 locomotive sequence.
     */
    public void thingA() {
        composer.s2(); composer.mms_87_StaggerUpDown(); composer.x2();
    }

    /**
     * Play a simple 4 locomotive sequence.
```

```
     */
    public void thingB() {
        composer.s2(); composer.mms_85_StrollDown(); composer.x2();
    }

}
```

The ABPlayerBach Java Class file

```
/*
 * Subclass of the abstract ABPlayer class which renders minuet like melodies
 * by binding A and B each to a 3 beat sequence lifted from a Bach minuet.
 */

package players;

import composer.SComposer;

public class ABPlayerBach extends ABPlayer {

    /**
     * Create a specialization of an ABPlayer which renders a minuet like
     * melody by sequencing fragments stolen from Bach minuets.
     * @param composer is the work horse composer
     */
    public ABPlayerBach(SComposer composer) {
        super(composer);
    }

    /**
     * Play a 5 note 3 beat sequence lifted from a Bach minuet.
     */
    public void thingA() {
        composer.mms_35_JSB_M9();
    }

    /**
     * Play a 4 note 3 beat sequence lifted from a Bach minuet.
     */
    public void thingB() {
        composer.mms_34_JSB_M7();
    }

}
```

Task 11: Establishment of the AlgaePlayer Java Main Class file

The following program makes use of the refinements of the `ABPlayer` class in order to play melodic sequences based on the Algae strings. It conditionally determines which Algea string to render, and which of the three renderers thus far established to employ. Study it. Then enter it.

The AlgaePlayer Java Class file

```
/*
 * This abstract class serves to render melodies based on strings of As and Bs.
 * The renderer is coded in such a way that the rendering of each symbol is
 * left left unspecified. To complete the renderer, the methods thingA and
 * thingB must be specified. That is the job of the classes which extend this
 * abstract class.
 */

package players;

import composer.SComposer;
import java.util.Random;
import java.util.Scanner;

public abstract class ABPlayer {

    // The simple composer is the sole instance variable for this class.

    protected SComposer composer;

    /**
     * Create an ABPlayer, a performer which bases its work on strings of As and
     * Bs. It is basically a simple composer (SComposer) which processes the As
     * and the Bs in the string, one at a time, by somehow sonically rendering
     * them.
     * @param c is the work horse painter
     */
    public ABPlayer(SComposer c) {
        composer = c;
    }

    /**
     * Play a melody by processing the given string of A and B symbols.
     * @param line is a string of As and Bs, presumably generated by some
     * L-System. But there is a "twist". An "add on" imposes stepwise
     * motion, for the most part, on the melodic fragments to which the
     * A and B are bound.
     */
    public void play(String line) {
        composer.beginScore();
        composer.text();
        String motionLine = motionLine(line) + "S";
        int x = 0;
        Scanner symbolString = new Scanner(line);
        while ( symbolString.hasNext() ) {
            String symbol = symbolString.next();
            if ( symbol.equals("A") ) {
                thingA();
            } else if ( symbol.equals("B") ) {
                thingB();
```

```
        }
        if ( symbolString.hasNext() ) {
            String direction = motionLine.substring(x,x+1);
            changePitch(composer,direction);
            x = x + 1;
        }
    }
    composer.mms_31_JSB_M1();
    composer.untext();
    composer.saveScore();
}

private String motionLine(String line) {
    System.out.println("line = " + line);
    int lineLength = lineLength(line);
    int motionLineLength = lineLength-1;
    String orderedMotionLine = orderedMotionLine(motionLineLength);
    String unorderedMotionLine = unorderedMotionLine(orderedMotionLine);
    System.out.println("Stepwise motion = " + unorderedMotionLine);
    return unorderedMotionLine;
}

private int lineLength(String line) {
    if ( line.equals("") ) {
        return 0;
    } else if ( line.substring(0,1).equals(" ") ) {
        return lineLength(line.substring(1));
    } else {
        return 1 + lineLength(line.substring(1));
    }
}

private String orderedMotionLine(int motionLineLength) {
    if ( motionLineLength == 0 ) {
        return "";
    } else if ( motionLineLength == 1 ) {
        return "S";
    } else {
        return "RL" + orderedMotionLine(motionLineLength-2);
    }
}

private String unorderedMotionLine(String orderedMotionLine) {
    if ( orderedMotionLine.length() < 2 ) {
        return orderedMotionLine;
    } else {
        String element = pick(orderedMotionLine);
        String remainder = remove(element,orderedMotionLine);
        return element + unorderedMotionLine(remainder);
    }
}

private Random generator = new Random();
```

```
    private String pick(String orderedMotionLine) {
        int rn = generator.nextInt(orderedMotionLine.length());
        return orderedMotionLine.substring(rn,rn+1);
    }

    private String remove(String element, String bag) {
        int position = bag.indexOf(element);
        return bag.substring(0,position) + bag.substring(position+1);
    }

    private void changePitch(SComposer composer, String direction) {
        if ( direction.equalsIgnoreCase("R") ) {
            composer.rp();
        } else if ( direction.equalsIgnoreCase("L") ) {
            composer.lp();
        } else if ( direction.equalsIgnoreCase("S") ) {

        }
    }

    /**
     * Reference to an encoding of what it means to render the A symbol
     * sonically.
     */
    public abstract void thingA();

    /**
     * Reference to an encoding of what it means to render the B symbol
     * sonically.
     */
    public abstract void thingB();

}
```

Task 12: Replicate the `AlgaePlayer` demo

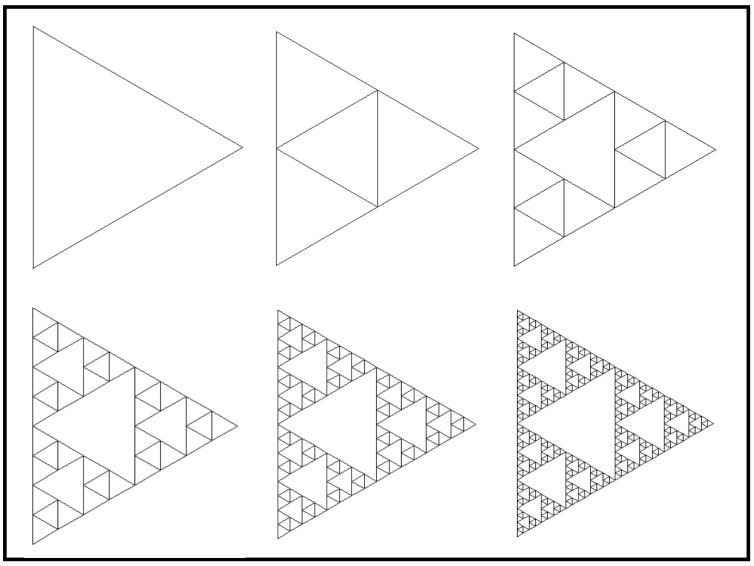
By now, you should have established, in your world, all of the code needed to replicate the demo of the `AlgaePlayer` that was previously presented. Run the `AlgaePlayer` program and replicate the demo!

Task 13: Change the *players* and generate a `AlgaePlayer` demo

By analogy with `ABPlayerBasics`, `ABPlayerLocomotions`, and `ABPlayerBach`, write corresponding Java classes `ABPlayerBasics2`, `ABPlayerLocomotions2`, and `ABPlayerBach2` which will generate three melodic lines when the programs are run which are interestingly different from those generated by the given programs. Simply study the three given programs, and then write three alternates. Run the `AlgaePlayer` program and interact with it to generate a demo quite like that which was previously presented – but which produces different melodic lines!

Task 14: Generating Sierpinski Triangle images

The Sierpinski Triangle is an example of a self similar object, or **fractal**. Fractals can be rendered at any level of complexity. Six renderings of the Sierpinski Triangle are presented in the following diagram:



These images have been generated by means of the previously presented L-System and a Turtle Geometry rendering scheme. At this point, you might like to Google "Turtle Geometry" and get acquainted with the basics of the system. The simple painter of the NPW was inspired by Turtle Geometry. For many purposes, you can forget that there is any distinction between the two. However you wish to conceive of the screen creature, this is the set of action bindings that is used to produce Sierpinski Triangles:

1. `F`: draw a line in the forward direction for some distance δ
2. `G`: draw a line in the forward direction for some distance δ
3. `+`: turn 120 degrees to the left
4. `-`: turn 120 degrees to the right

The six images shown were produced by means of running the `SierpinskiTrianglePainter` program as shown in the subsequent demo. (Each image was clipped from the canvas and subsequently merged into a composite image by hand.

After studying the demo in relation to the images, please study the accompanying code that forms an interpreter for deriving generations of the Sierpinski L-System and rendering corresponding Sierpinski Triangles. Then, type it in, and run it, mimicking the demo.

(You may have guessed that a variant of this program was used to create the connect-the-dots opportunity which appears on the front cover of this manual.)

Standard IO demo of `SierpinskiTrianglePainter`

```
run:
SierpinskiTriangle>>> help
HELP - display this help menu to the standard output stream
DISPLAY - display the L-System, vocabulary and axiom and productions
GENERATE - generate some number of generations, as specified by the user
PAINT - paint a rendering of some generation of the system
SLOW - slow down the painting, if it is fast
FAST - slow down the painting, if it is slow
DISPOSE - get rid of the canvas on which the rendering was painted
EXIT - terminate execution of this program
SierpinskiTriangle>>> display
Name = SierpinskiTriangle
Axiom = F - G - G
Productions ...
F --> F - G + F + G - F
G --> G G
- --> -
+ --> +
SierpinskiTriangle>>> generate
How many generations? 4
generation 0 = F - G - G
generation 1 = F - G + F + G - F - G G - G G
generation 2 = F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G
  - G G G G
generation 3 = F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G
  + F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F + G G G G - F - G +
  F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G G G G G - G G G G G
  G G G
generation 4 = F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G
  + F - G + F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F + G G G G - F - G +
  F + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G G G G G + F - G + F
  + G - F - G G + F - G + F + G - F + G G - F - G + F + G - F - G G G G + F - G + F + G - F -
  G G + F - G + F + G - F + G G - F - G + F + G - F + G G G G - F - G + F + G - F - G G + F -
  G + F + G - F + G G - F - G + F + G - F + G G G G G G G G - F - G + F + G - F - G G + F - G
  + F + G - F + G G - F - G + F + G - F - G G G G + F - G + F + G - F - G G + F - G + F + G -
  F + G G - F - G + F + G - F + G G G G - F - G + F + G - F - G G + F - G + F + G - F + G G -
  F - G + F + G - F - G G G G G G G G G G G G G G G G G G - G G G G G G G G G G G G G G G G G
SierpinskiTriangle>>> paint
Generation number? 0
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> paint
Generation number? 1
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> paint
Generation number? 2
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> paint
Generation number? 3
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> paint
```

```
Generation number? 4
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> paint
Generation number? 5
SierpinskiTriangle>>> dispose
SierpinskiTriangle>>> exit
BUILD SUCCESSFUL (total time: 1 minute 28 seconds)
```

SierpinskiTrianglePainter program

```
/*
 * This program can generate and process generations of the Sierpinski Triangle
 * L-System, where processing amounts to performing graphical renderings of the
 * strings of symbols A and B of the system. The program takes the form of an
 * interpreter. See the comment prefacing the constructor for additional details.
*/

package lsystem;

import java.util.ArrayList;
import java.util.List;
import java.util.Scanner;
import javax.swing.SwingUtilities;
import painter.SPainter;
import painters.STPainter;
import painters.STPainterStar;

public class SierpinskiTrianglePainter extends LSystem {

    /**
     * Create an SierpinskiTrianglePainter object, which is so tightly coupled to
     * its behavior as an interpreter that its private interpreter method is
     * called from this constructor. The program can represent the Algae
     * L-System, and can derive successive generations of strings within
     * the system. Specifically, the interpreter can process the following
     * commands: <br>
     * *  HELP - display this help menu to the standard output stream<br>
     * *  DISPLAY - display the L-System, vocabulary and axiom and productions<br>
     * *  GENERATE - generate some number of generations, as specified by the user<br>
     * *  PAINT - paint a rendering of some generation of the system<br>
     * *  SLOW - slow down the painting, if it is fast<br>
     * *  FAST - speed up the painting, if it is slow<br>
     * *  DISPOSE - get rid of the canvas on which the rendering was painted<br>
     * *  EXIT - terminate execution of this program<br>
     */
    public SierpinskiTrianglePainter() {
        super("SierpinskiTriangle");
        axiom = "F - G - G";
        productions = productions();
        interpreter();
    }
```

```
private List<Production> productions() {
    Production p1 = new Production("F","F - G + F + G - F");
    Production p2 = new Production("G","G G");
    Production p3 = new Production("-","-");
    Production p4 = new Production("+","+");
    ArrayList<Production> productions = new ArrayList<>();
    productions.add(p1);
    productions.add(p2);
    productions.add(p3);
    productions.add(p4);
    return productions;
}


private void interpreter() {
    Scanner scanner = new Scanner(System.in);
    System.out.print("SierpinskiTriangle>>> ");
    String line = scanner.next();
    if ( line.equalsIgnoreCase("exit") ) {
        System.exit(0);
    } else if ( line.equalsIgnoreCase("generate") ) {
        generate();
    } else if ( line.equalsIgnoreCase("paint") ) {
        paint();
    } else if ( line.equalsIgnoreCase("slow") ) {
        waitTime =500;
    } else if ( line.equalsIgnoreCase("fast") ) {
        waitTime = 0;
    } else if ( line.equalsIgnoreCase("dispose") ) {
        miro.end();
    } else if ( line.equalsIgnoreCase("help") ) {
        help();
    } else if ( line.equalsIgnoreCase("display") ) {
        System.out.print(toString());
    } else {
        System.out.println("Sorry, I don't recognize: " + line);
    }
    interpreter();
}

private static void help() {
    System.out.println("HELP - display this help menu to " +
            "the standard output stream");
    System.out.println("DISPLAY - display the L-System, " +
            "vocabulary and axiom and productions");
    System.out.println("GENERATE - generate some number of generations, " +
            "as specified by the user");
    System.out.println("PAINT - paint a rendering of some generation of the system");
    System.out.println("SLOW - slow down the painting, if it is fast");
    System.out.println("FAST - slow down the painting, if it is slow");
    System.out.println("DISPOSE - get rid of the canvas " +
            "on which the rendering was painted");
    System.out.println("EXIT - terminate execution of this program");
```

```
    }

    private SPainter miro;
    private int waitTime = 0;

    private void paint() {
        Scanner scanner = new Scanner(System.in);
        System.out.print("Generation number? ");
        int generationNumber = scanner.nextInt();
        miro = new SPainter(900,900);
        STPainterStar painter = new STPainterStar(miro);
        painter.paint(generationNumber,generation(generationNumber),waitTime);
    }

    /**
     * Simply sets up the infrastructure for the program, and gets things started.
     * @param args is not used
     */
    public static void main(String[] args) {
      SwingUtilities.invokeLater(new Runnable() {
         public void run() {
            new SierpinskiTrianglePainter();
         }
      });
    }

}
```

Task 15: Cantor Dust painting

By analogy with the `AlgaePainter` program, write a `CantorDustPainter` program. Notice that the Cantor L-System has a vocabulary of just two symbols, A and B, so that you can make use of the `ABPainter` program as is. By analogy with the `ABPainterALines` program write an `ABPainterCDLines` program. By analogy with the `ABPainterACircles` program write an `ABPainterCDCircles` program. By analogy with the `ABPainterASquares` program write an `ABPainterCDSquares` program. Then, run the `CantorDustPainter` program to generate three images, one based on lines, one based on circles, and one based on squares.

Task 16: Cantor Dust playing

By analogy with the `AlgaePlayer` program, write a `CantorDustPlayer` program. Again, notice that the Cantor L-System has a vocabulary of just two symbols, A and B, so that you can make use of the `ABPainter` program as is. By analogy with the `ABPlayerBasics` program write an `ABPainterCDBasics` program. By analogy with the `ABPainterALocomotives` program write an `ABPainterCDLocomotives` program. By analogy with the `ABPainterABach` program write an `ABPainterCDBach` program. Then, run the `CantorDustPainter` program to generate three images, one based on the simple composer's basics, one based on the simple composer's locomotives, and one based on the simple composer's stash of Bach sequences.

Task 17: Generate the *Javadocs* for your `CS1` project

Generate the *Javadocs* for your `CS1` project. Google how to do it, if you should need to. (It is very easy!) Take a good look at the Web documents that are generated for your L-System programs, in particular.

Task 18: Incorporate artifacts into your site

Incorporate code, images, and sound files into your work site as you see fit.

Task 19: Reflection

Think for a little while about this lab and your engagement with it. What did you learn that is conceptually significant? What did you learn that is technologically useful? What is your most salient thought about the lab and your engagement with it?

31 Exit

C. A. R. Hoare on COMPUTER SCIENCE

What is the central core of the subject [computer science]? What is it that distinguishes it from the separate subjects with which it is related? What is the linking thread which gathers these disparate branches into a single discipline. My answer to these questions is simple - it is the art of programming a computer. It is the art of designing efficient and elegant methods of getting a computer to solve problems, theoretical or practical, small or large, simple or complex. It is the art of translating this design into an effective and accurate computer program.

Perspective

This text, and the course to which it contributes, are centered on *programming in the small*. If you methodically worked through all of the labs, and if you dedicated yourself to completing the programming assignments, you probably have a pretty good idea of how one person goes about writing a relatively small, relatively simple computer program. But you should know that this is just a part of the field of computer science. There are many other parts, as well. One of these other parts can be characterized as *programming in the large*. This pertains to writing large software systems. Teams of programmers are involved, and systems of *modules* are designed to fit together in elegant ways, ways that ideally afford ease of maintenance, modification, and extension. The CS2 course is designed to refine and expand your knowledge of programming in the small. Other courses in the curriculum explore ideas and issues surrounding programming in the large. Programming in the small vs programming in the large is just one of many dichotomous ways to think about aspects of computer science. The field is huge, packed with powerful ideas, and constantly pregnant with respect to practical applications.

Although computer science knowledge can certainly lead to attractive careers in terms of monetary reward and professional satisfaction, it is perhaps the fact that computer science is associated with *a way of thinking* that recommends it more than any other for a position in the college curriculum.

$\Longrightarrow$ Why study computer science? **To learn a powerful way of thinking!**

Summary of the Most Salient Elements of the Laboratories

1. **Lab 1: Hello World! Hello You!** ▷ Java ◇ Integrated Development Environment (IntelliJ) ◇ templates ◇ program execution ◇ program IO ◇ widgets ◇ appreciating the importance of tending to detail at the level of the token
2. **Lab 2: Hello Painter! Hello Composer!** ▷ object creation ◇ object use ◇ library files ◇ microworlds ◇ Nonrepresentational Painting World (NPW) ◇ Modular Melody World (MMW) ◇ graphics programming ◇ sonic programming
3. **Lab 3: Establishing a CS1 Work Site** ▷ Emacs ◇ HTML ◇ CSS ◇ Web development ◇ file structure ◇ source files ◇ graphics files
4. **Lab 4: Expressions and Shapes World Problem Solving** ▷ fully parenthesized expression ◇ English/Java representations of arithmetic expressions ◇ simple geometric/algebraic problem solving ◇ Crypto problem solving ◇ problem solving with simple shape objects ◇ inscribing circles ◇ circumscribing circles

5. **Lab 5: An Interpreter Featuring *Loop Forever* and Selection** ▷ interpreters ◇ loop forever ◇ break statement ◇ multiway conditional statement ◇ random number generation ◇ dialog box ◇ string comparison
6. **Lab 6: Functions and Commands** ▷ define functions ◇ define commands ◇ apply the principle of stepwise refinement ◇ work with IntelliJ to effectively engage in stepwise refinement ◇ program by modifying an extant program ◇ while statement ◇ conditional execution ◇ generate random colors
7. **Lab 7: String Thing** ▷ get acquainted with `length`, `indexOf`, two versions of the `substring` function, and the `equalsIgnoreCase` function◇ mindfully perform *abstraction* by writing methods to generalize on specific computations ◇ attend to detail with respect to positions of items in a sequence
8. **Lab 8: Array Play** ▷ array declaration ◇ array creation ◇ array indexing ◇ file processing ◇ exceptions ◇ program by analogy ◇ data file creation
9. **Lab 9a: Simple List Processing** ▷ `ArrayList` ◇ generics ◇ list methods: `add`, `set` `get`, `size` ◇ comparing/contrasting arrays and lists
10. **Lab 9b: List Processing with Streams** ▷ `String.join` ◇ use Java streams ◇ stream transformation functions: `map`, `filter`, `reduce` ◇ collect the results from stream processing ◇ write programs that do the same thing in multiple ways
11. **Lab 10: Establishing and Using Classes** ▷ refining pseudocode ◇ "mechanical" translation of code ◇ data control loop vs counter control loop ◇ generating and refining stubs
12. **Lab 11: Modeling Objects with Classes** ▷ class definition ◇ establish instance variables ◇ define constructors ◇ define methods ◇ establish an interface ◇ implement an interface
13. **Lab 12: Grapheme to Color Synesthesia** ▷ parallel arrays ◇ sequential search ◇ drawing text ◇ mapping ◇ synesthetic simulation
14. **Lab 13: Chromesthesia** ▷ incremental program development ◇ mapping pitch classes to sounds ◇ integrate graphic processing with sonic processing ◇ simulate the experience of a chromesthete ◇ process arrays of objects ◇ symbolic processing ◇ scanning/interpretation
15. **Lab 14: Fun with Fractals** ▷ self-similarity ◇ fractals ◇ L-Systems ◇ programming generative algorithms ◇ abstract classes ◇ algorithmic composition ◇ Turtle Geometry

32 Appendix 1: Nonrepresentational Painting World (NPW)

This appendix presents a partial specification of the Nonrepresentational Painting World, or NPW, which features (1) two-dimensional *shape* objects, and (2) *simple painter* objects that can render the shapes in various ways on a 2D area called the *canvas*. This environment affords opportunities to explore ideas associated with the world of nonrepresentational art and the work of graphic design. Only the most basic elements of functionality are presented here.

Interpreting Entries in the Appendices

Each entry in this appendix is made up of `terminal` symbols and *`non-terminal`* symbols. Terminal symbols are those which require no modification by you – type them exactly as shown. Non-terminal symbols stand for something of the specified type, and should be replaced with something appropriate to the type specified. For example, in order to use the version of `paint` which takes an *`SCircle`* argument:

`SPainter``.paint(`*`SCircle`*`)`

you must replace *`SPainter`* and *`SCircle`* with instances of the appropriate types.

Methods and constructors which return values have the types of those values shown after the $\longrightarrow$ symbol. For example, you can see below that the constructors for `SPainter` return instances of that type.

SPainter Functionality

A *simple painter* is a screen creature that is bound to a 2D graphics area, called its *canvas*. The painter can move about the canvas and *paint* (fill in) or *draw* (outline) shapes of various sorts on the canvas, provided they are within reach. A *painter* is modeled in terms of several properties, most notably its *location*, and its *heading*. To do its rendering tasks, the painter possesses a *brush*, which has a *width*, and which can render shapes in virtually any *color*. There are a number of constructors associated with the `SPainter` class, including:

- `new SPainter(`*`String`*`, `*`int`*`, `*`int`*`)` $\longrightarrow$ *`SPainter`*
  returns a simple painter in a canvas, labelled by the given string, the width and height of which are equal to the two integer values
- `new SPainter(`*`int`*`, `*`int`*`)` $\longrightarrow$ *`SPainter`*
  returns a simple painter in an undecorated (no close or shrink boxes), unlabelled black framed canvas, the width and height of which are equal to the two integer values

There is functionality to move the painter forward, backward, right or left, with respect to the direction in which it is facing, to turn it in various ways, to paint and draw certain shapes, to draw text, and to do a number of other things.:

- *`SPainter`*`.canvasHeight()` $\longrightarrow$ *`int`*
  returns the height of the canvas (including 22 for the top bar, if there is one)
- *`SPainter`*`.canvasWidth()` $\longrightarrow$ *`int`*
  returns the width of the canvas
- *`SPainter`*`.center()` $\longrightarrow$ *`Point2D.Double`*
  returns the center point on the canvas

- `SPainter.cvtDegToRad(`*`double`*`)` ⟶ *`double`*
  converts the given number of degrees to the corresponding number of radians
- *`SPainter`*`.dbk(`*`double`*`)`
  the painter moves backward the given distance with respect to its present heading, leaving a trace
- *`SPainter`*`.dfd(`*`double`*`)`
  the painter moves forward the given distance with respect to its present heading, leaving a trace
- *`SPainter`*`.draw(`*`SCircle`*`)`
  draws (the border of) the given circle around to painter, using the current paint color
- *`SPainter`*`.draw(`*`SPolygon`*`)`
  draws (the border of) the given polygon around to painter, using the current paint color
- *`SPainter`*`.draw(`*`SRectangle`*`)`
  draws (the border of) the given rectangle around to painter, using the current paint color
- *`SPainter`*`.draw(`*`SSquare`*`)`
  draws (the border of) the given square around to painter, using the current paint color
- *`SPainter`*`.draw(`*`String`*`)`
  draws the string centered around the painter, horizontally
- *`SPainter`*`.drawLineTo(`*`Point2D.Double`*`)`
  the painter draws a line from its current position to the position given by the point, in the current color, and remains at the given point
- *`SPainter`*`.drawLineToI(`*`Point2D.Double`*`)`
  the painter draws a line from its current position to the position given by the point, in the current color, and then returns to the starting point
- *`SPainter`*`.faceNorth()`
  directs the painter to set its heading to 0 degrees (face north)
- *`SPainter`*`.frame()` ⟶ *`SRectangle`*
  returns the bordering rectangle of the canvas
- *`SPainter`*`.getBoundingRectangle()` ⟶ *`Rectangle2D.Double`*
  get the Java 2D rectangle which bounds the canvas
- *`SPainter`*`.getBoundingSuperRectangle()` ⟶ *`Rectangle2D.Double`*
  get a Java 2D rectangle which is a bit larger thang the one which bounds the canvas
- *`SPainter`*`.heading()` ⟶ *`double`*
  returns the painter's current heading, [0,360)
- *`SPainter`*`.mbk(`*`double`*`)`
  the painter moves backward the given distance with respect to its present heading, without leaving a trace
- *`SPainter`*`.mfd(`*`double`*`)`
  the painter moves forward the given distance with respect to its present heading, without leaving a trace
- *`SPainter`*`.mlt(`*`double`*`)`
  the painter moves to its left the given distance with respect to its present heading, without leaving a trace
- *`SPainter`*`.move()`
  moves the painter to a random position (location) on the canvas
- *`SPainter`*`.moveTo(`*`Point2D.Double`*`)`
  sets the position (location) of the painter to the (x,y) coordinates embedded within the given point, with respect to the top-left corner of the canvas
- *`SPainter`*`.moveToCenter()`
  move the painter to the center of the canvas
- *`SPainter`*`.moveWithinNeighborhood(`*`int`*`)`
  move the painter to a position within the circle of radius equal to the given number centered at the location of the painter, without changing the heading of the painter
- *`SPainter`*`.mrt(`*`double`*`)`
  the painter moves to its right the given distance with respect to its present heading, without leaving a trace
- *`SPainter`*`.paint(`*`SCircle`*`)`
  paint the given circle around to painter, using the current paint color

- *SPainter*.paint(*SPolygon*)
  paint the given polygon around to painter, using the current paint color
- *SPainter*.paint(*SRectangle*)
  paint the given rectangle around to painter, using the current paint color
- *SPainter*.paint(*SSquare*)
  paint the given square around to painter, using the current paint color
- *SPainter*.paintBrushColor() ⟶ *Color*
  returns the color currently on the painter's brush
- *SPainter*.paintFrame(*Color*,*int*)
  paint a border around the painter's canvas of width equal to the given integer and of color equal to the given color
- *SPainter*.pause()
  ask the painter to pause for 1 second
- *SPainter*.pause(*int*)
  ask the painter to pause for the given number of milliseconds second
- *SPainter*.position() ⟶ *Point2D.Double*
  return the painter's position (location) on the canvas
- *SPainter*.random() ⟶ *Point2D.Double*
  returns a random point on the canvas
- *SPainter*.restoreColor()
  restore the most recently saved paint color
- *SPainter*.saveColor()
  save the current paint color
- *SPainter*.setBrushWidth(*int*)
  set the painter's brush width to the given value
- *SPainter*.setColor(*Color*)
  set the color that the painter will draw or paint with to the given color
- *SPainter*.setFontSize(*int*)
  set the font size to the given value
- *SPainter*.setHeading(*int*)
  the painter sets its heading to the given value
- *SPainter*.setPosition(*Point2D.Double*)
  sets the position (location) of the painter to the (x,y) coordinates embedded in the given point, with respect to the top-left corner of the canvas
- *SPainter*.setRandomColor()
  set the color that the painter will draw or paint with to a random color
- *SPainter*.setRandomBlueColor()
  set the color that the painter will draw or paint with to a random blue color
- *SPainter*.setRandomGreenColor()
  set the color that the painter will draw or paint with to a random green color
- *SPainter*.setRandomRedColor()
  set the color that the painter will draw or paint with to a random red color
- *SPainter*.setScreenLocation(*int*, *int*)
  place the painter's frame, the upper left corner, at the screen location given
- *SPainter*.setVisible(*boolean*)
  makes the frame within which the painter is housed appear or disappear on the screen
- *SPainter*.ta()
  the painter does an about face
- *SPainter*.tl()
  the painter turns 90 degrees to its left
- *SPainter*.tr()
  the painter turns 90 degrees to its right

- *SPainter*.wash()
  simply white wash the canvas

SShapes Functionality

SCircle Functionality

A *simple circle* is modeled in terms of just one property, its *radius*. There is just one constructor associated with the SCircle class, which takes the radius of the new circle as its sole parameter.

- new SCircle(*double*) ⟶ *SCircle*
  return a *simple circle*, the radius of which is given by the real number

There is functionality for solving simple problems involving circles and for creating images based on circles, including:

- *SCircle*.area() ⟶ *double*
  return the area of the circle
- *SCircle*.circumscribingPolygon(*int*) ⟶ *SPolygon*
  return the circumscribing polygon of the given degree of the circle
- *SCircle*.circumscribingSquare() ⟶ *SSquare*
  return the circumscribing square of the circle
- *SCircle*.diameter() ⟶ *double*
  return the diameter of the circle
- *SCircle*.expand(*double*)
  increase the radius of the circle by the given number
- *SCircle*.inscribingPolygon(*int*) ⟶ *SPolygon*
  return the inscribing polygon of the given degree of the circle
- *SCircle*.inscribingSquare() ⟶ *SSquare*
  return the inscribing square of the circle
- *SCircle*.perimeter() ⟶ *double*
  return the perimeter of the circle
- *SCircle*.radius() ⟶ *double*
  return the radius of the circle
- *SCircle*.s2()
  halve the radius by the circle
- *SCircle*.s3()
  shrink the radius by the circle by a factor of 3
- *SCircle*.s5()
  shrink the radius by the circle by a factor of 5
- *SCircle*.s7()
  shrink the radius by the circle by a factor of 7
- *SCircle*.setRadius(*double*)
  set the radius by the circle to the given number
- *SCircle*.shrink(*double*)
  decrease the radius of the circle by the given number
- *SCircle*.toString() ⟶ *String*
  return a string representation of the circle
- *SCircle*.x2()
  double the radius by the circle

- *SCircle*.x3()
  expand the radius by the circle by a factor of 3
- *SCircle*.x5()
  expand the radius by the circle by a factor of 5
- *SCircle*.x7()
  expand the radius by the circle by a factor of 7

SPolygon Functionality

A *simple polygon* is modeled in terms of two properties, its *degree* (number of sides) and its *side* (side length). There is just one constructor associated with the SPolygon class, which takes two parameters, the degree and the side of the polygon.

- new SPolygon(*int*,*double*) ⟶ *SPolygon*
  return a *simple polygon*, the degree of which is given by the integer, and the side of which is given by the real number

There is functionality for solving simple problems involving polygons and for creating images based on polygons, including:

- *SPolygon*.area() ⟶ *double*
  return the area of the polygon
- *SPolygon*.circumscribingCircle() ⟶ *SCircle*
  return the circumscribing circle of the polygon
- *SPolygon*.dec()
  decrement the degree of the polygon by 1
- *SPolygon*.decSide()
  decrement the side of the polygon by 1
- *SPolygon*.degree() ⟶ *double*
  return the degree of the polygon
- *SPolygon*.inc()
  increment the degree of the polygon by 1
- *SPolygon*.incSide()
  increment the side of the polygon by 1
- *SPolygon*.inscribingCircle() ⟶ *SCircle*
  return the inscribing circle of the polygon
- *SPolygon*.perimeter() ⟶ *double*
  return the perimeter of the polygon
- *SPolygon*.setSide(*double*)
  set the side of the polygon to the given number
- *SPolygon*.side() ⟶ *double*
  return the side (length) of the polygon
- *SPolygon*.toString() ⟶ *String*
  return a string representation of the polygon

SRectangle Functionality

A *simple rectangle* is modeled in terms of just two properties, its *height* and its *width*. There is just one constructor associated with the SRectangle class, which takes two parameter, the height and the width of the rectangle.

- `new SRectangle(`*`double`*`,`*`double`*`)` ⟶ *`SRectangle`*
  return a new simple rectangle, the height of which is given by the first number, and the width of which is given by the second number

There is functionality for solving simple problems involving rectangles and creating images based on rectangles, including:

- *`SRectangle`*`.area()` ⟶ *`double`*
  return the area of the rectangle
- *`SRectangle`*`.diagonal()` ⟶ *`double`*
  return the diagonal of the rectangle
- *`SRectangle`*`.expand(`*`double`*`,`*`double`*`)`
  expand the height of the rectangle by adding the first value to it, and expand the width of the rectangle by adding the second value to it
- *`SRectangle`*`.height()` ⟶ *`double`*
  return the height of the rectangle
- *`SRectangle`*`.perimeter()` ⟶ *`double`*
  return the perimeter of the rectangle
- *`SRectangle`*`.shrink(`*`double`*`,`*`double`*`)`
  shrink the height of the rectangle by subtracting the first value from it, and shrink the width of the rectangle by subtracting the second value from it
- *`SRectangle`*`.setHeight(`*`double`*`)`
  set the height of the rectangle to the given value
- *`SRectangle`*`.setWidth(`*`double`*`)`
  set the width of the rectangle to the given value
- *`SRectangle`*`.toString()` ⟶ *`String`*
  return a string representation of the rectangle
- *`SRectangle`*`.width()` ⟶ *`double`*
  return the width of the rectangle

SSquare Functionality

A *simple square* is modeled in terms of just one property, its *side* (side length). There is just one constructor associated with the `SSquare` class, which takes the side of the new square as its sole parameter.

- `new SSquare(`*`double`*`)` ⟶ *`SSquare`*
  return a *simple square*, the side of which is given by the real number

There is functionality for solving simple problems involving squares and creating images based on squares, including:

- *`SSquare`*`.area()` ⟶ *`double`*
  return the area of the square
- *`SSquare`*`.circumscribingCircle()` ⟶ *`SCircle`*
  return the circumscribing circle of the square
- *`SSquare`*`.diagonal()` ⟶ *`double`*
  return the diagonal of the circle
- *`SSquare`*`.expand(`*`double`*`)`
  increase the radius of the circle by the given number
- *`SSquare`*`.inscribingCircle()` ⟶ *`SCircle`*
  return the inscribing circle of the square

- *SSquare*.perimeter() ⟶ *double*
  return the perimeter of the square
- *SSquare*.s2()
  halve the radius by the square
- *SSquare*.s3()
  shrink the side by the square by a factor of 3
- *SSquare*.s5()
  shrink the side by the square by a factor of 5
- *SSquare*.s7()
  shrink the side by the square by a factor of 7
- *SSquare*.setSide(*double*)
  set the sides of the square to the given number
- *SSquare*.shrink(*double*)
  decrease the side of the square by the given number
- *SSquare*.side() ⟶ *double*
  return the side (length) of the square
- *SSquare*.toString() ⟶ *String*
  return a string representation of the square
- *SSquare*.x2()
  double the side by the square
- *SSquare*.x3()
  expand the side by the square by a factor of 3
- *SSquare*.x5()
  expand the side by the square by a factor of 5
- *SSquare*.x7()
  expand the side by the square by a factor of 7

33 Appendix 2: Modular Melody World (MMW)

This appendix presents a partial specification for the Modular Melody World, or MMW, which features musical *note* objects and music *composer* objects, both of which can be used to render melodic sequences of notes. Some, not all, elements of this microworld's functionality is presented here.

Interpreting Entries in the Appendices

Each entry in this appendix is made up of `terminal` symbols and *`non-terminal`* symbols. Terminal symbols are those which require no modification by you – type them exactly as shown. Non-terminal symbols stand for something of the specified type, and should be replaced with something appropriate to the type specified. For example, in order to use the `changeVolume` method, which takes a *`String`* argument:

`SNote``.changeVolume(`*`String`*`)`

you must replace *`SNote`* and *`String`* with instances of the appropriate types.

Methods and constructors which return values have the types of those values shown after the $\longrightarrow$ symbol. For example, you can see below that the constructor for `SComposer` returns an instance of that type.

SComposer Functionality

A *simple composer* may be thought of as an agent that can help you to craft melodic lines. A composer possesses a *note*, and knows how do a variety of things with it, the most notable of which is to play *modular melodic sequences* with it.

- `new SComposer()` $\longrightarrow$ *`SComposer`*
  return a *simple composer* whose *note* is instantiated to the default values associated with a simple note, namely: `degree=C-MAJOR`, `degree=1`, `duration=1`, `timbre=PIANO`, and `volume=MEDIUM`

There is simple composer's functionality includes:

- *`SComposer`*`.beginScore()`
  begin a midi score
- *`SNote`*`.changeVolume(`*`String`*`)`
  sets the volume according to the given number, scale "0" .. "12000"
- *`SComposer`*`.cp()`
  either raise the pitch or lower the pitch one scale degree
- *`SComposer`*`.doubleTime()`
  change the tempo, increasing it by a factor of two (functionally the same as s2, but intended for a conceptually different use)
- *`SComposer`*`.halfTime()`
  change the tempo, decreasing it by a factor of two (functionally the same as x2, but intended for a conceptually different use)
- *`SComposer`*`.loud()`
  set the volume of the note to 12500
- *`SComposer`*`.lp()`
  lower the composer's note one scale degree

- *SComposer*.lp(*int*)
  lower the composer's note the given number of scale degrees
- *SComposer*.maxx()
  set the volume of the note to 15000
- *SComposer*.medd()
  set the volume of the note to 10000
- *SComposer*.minn()
  set the volume of the note to 2500
- *SComposer*.mms1()
  a simple modular melodic sequence
- *SComposer*.mms2()
  a simple modular melodic sequence
- *SComposer*.mms3()
  a simple modular melodic sequence
- *SComposer*.mms4()
  a simple modular melodic sequence
- *SComposer*.mms5()
  a simple modular melodic sequence
- *SComposer*.mms6()
  a simple modular melodic sequence
- *SComposer*.mms7()
  a simple modular melodic sequence
- *SComposer*.mms8()
  a simple modular melodic sequence
- *SComposer*.mms_31_JSB_M1()
  a modular melodic sequence consisting of 1 note in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_33_JSB_M2()
  a modular melodic sequence consisting of 3 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_33_JSB_M3()
  a modular melodic sequence consisting of 3 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_33_JSB_M4()
  a modular melodic sequence consisting of 3 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_33_JSB_M5()
  a modular melodic sequence consisting of 3 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_34_JSB_M6()
  a modular melodic sequence consisting of 4 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_34_JSB_M7()
  a modular melodic sequence consisting of 4 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_34_JSB_M8()
  a modular melodic sequence consisting of 4 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_35_JSB_M9()
  a modular melodic sequence consisting of 5 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_35_JSB_M10()
  a modular melodic sequence consisting of 5 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_35_JSB_M11()
  a modular melodic sequence consisting of 5 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_35_JSB_M12()
  a modular melodic sequence consisting of 5 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_35_JSB_M13()
  a modular melodic sequence consisting of 5 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_36_JSB_M14()
  a modular melodic sequence consisting of 6 notes in 3 beats, the shape of which was lifted from a Bach minuet

- *SComposer*.mms_36_JSB_M15()
  a modular melodic sequence consisting of 6 notes in 3 beats, the shape of which was lifted from a Bach minuet
- *SComposer*.mms_85_HillFlat()
  a modular melodic sequence consisting of 5 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_86_HillStones()
  a modular melodic sequence consisting of 6 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_Hill()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_88_Hills()
  a modular melodic sequence consisting of 8 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_86_PrepJump()
  a modular melodic sequence consisting of 6 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_Stagger()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_StaggerUpDown()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_Stroll()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_StrollUpDown()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_85_StrollDown()
  a modular melodic sequence consisting of 5 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_ZagZig()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.mms_87_ZigZag()
  a modular melodic sequence consisting of 7 notes in 8 beats whose shape iconically resembles its name
- *SComposer*.play()
  play the composer's note
- *SComposer*.rest()
  rest the composer's note
- *SComposer*.rp()
  raise the composer's note one scale degree
- *SComposer*.rp(*int*)
  raise the composer's note the given number of scale degrees
- *SComposer*.saveScore()
  assuming that you have begun a score, the midi representation of the score that has been defined by playing the composer's note to the point of this method call will be written to the file that you are asked to specify, provided you specify a valid file name in the proper way (be sure the directory that you are eyeing already exists)
- *SComposer*.s2()
  shrink the composer's note by a factor of 2
- *SComposer*.s3()
  shrink the composer's note by a factor of 3
- *SComposer*.s5()
  shrink the composer's note by a factor of 5
- *SComposer*.soft()
  set the volume of the note to 7500
- *SComposer*.text()
  play and rest of the note textually (as well as sonically)
- *SComposer*.untext()
  stop the playing and resting the note textually (as well as sonically)
- *SComposer*.x2()

expand the composer's note by a factor of 2

- *SComposer*.x3()
  expand the composer's note by a factor of 3
- *SComposer*.x5()
  expand the composer's note by a factor of 5

SNote Functionality

A *simple note* is modeled in terms of more than a dozen properties, the most salient of which are `scale` and `degree`, which collectively define the *pitch* of the note, `duration` which is measured in some number of beats, the `timbre` of a note, which pertains to the "instrument" through which the note may be rendered, and the `volume` of the note.

- `new SNote()` $\longrightarrow$ *SNote*
  return a *simple note* with default values of `degree`=`C-MAJOR`, `degree`=`1`, `duration`=`1`, `timbre`=`PIANO`, and `volume`=`MEDIUM`

There is functionality for playing the note, resting the note, changing the degree, duration, volume, timbre, and other dimensions of the note. This functionality includes:

- *SNote*.beginScore()
  begin a midi score
- *SNote*.changeVolume(*String*)
  sets the volume according to the given number, scale "0" .. "12000"
- *SNote*.cp()
  either raise the pitch or lower the pitch one scale degree
- *SNote*.loud()
  set the volume of the note to 12500
- *SNote*.lp()
  lower the pitch of the note one scale degree
- *SNote*.lp(*int*)
  lower the pitch of the note the given number of scale degrees (within reason)
- *SNote*.maxx()
  set the volume of the note to 15000
- *SNote*.medd()
  set the volume of the note to 10000
- *SNote*.minn()
  set the volume of the note to 2500
- *SNote*.play()
  play the note
- *SNote*.rest()
  rest the note
- *SNote*.rp()
  raise the pitch of the note one scale degree
- *SNote*.rp(*int*)
  raise the pitch of the note the given number of scale degrees (within reason)
- *SNote*.saveScore()
  assuming that you have begun a score, the midi representation of the score that has been assembled to the point of this method call will be written to the file that you are asked to specify, provided you specify a valid file name in the proper way (be sure the directory that you are eyeing already exists)
- *SNote*.shhh()
  set the volume of the note to 5000

- *SNote*.s2()
  shrink the duration of the note by a factor or 2
- *SNote*.s3()
  shrink the duration of the note by a factor or 3
- *SNote*.s5()
  shrink the duration of the note by a factor or 5
- *SNote*.soft()
  set the volume of the note to 7500
- *SNote*.text()
  play and rest of the note textually (as well as sonically)
- *SNote*.untext()
  stop the playing and resting the note textually (as well as sonically)
- *SNote*.x2()
  expand the duration of the note by a factor or 2
- *SNote*.x3()
  expand the duration of the note by a factor or 3
- *SNote*.x5()
  expand the duration of the note by a factor or 5

34 Resources and References

For the most part, the items listed below served to inform my thinking with respect to framing the course and crafting the text. Some of the items were actually referenced in the text.

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