CSC 308 Lecture Notes Week 4
Requirements Inspection Testing
Introduction to Requirements Modeling

I. This weeks material:

A. Milestones 3 and 4 writeup

B. SOP Volume 2: Requirements Testing

C. Java as an Abstract Modeling Language

D. milestone 4 example

II. Lab quiz this Friday, 30 January.

A. Covers material on SVN Basics handout and Week 4 lab notes.

B. Questions will be in terms of command-line interface to SVN.

C. There will be no questions on SVN clients.

III. Preparation for Week 5 requirements walkthroughs.

A. *Everyone must attend* all of the walkthroughs.

B. They will be held during lab on Monday through Friday, February 2 through 6, per the following schedule:

Time	**Day**	**Team**
12:10 - 12:34	Mon 2 Feb	DJ Cars
12:36 - 1:00	Mon 2 Feb	TokenCSC
12:10 - 12:34	Wed 4 Feb	Team 0
12:36 - 12:00	Wed 4 Feb	Fire Breathing Rubber Duckies
12:10 - 12:34	Fri 6 Feb	Node
12:36 - 1:00	Fri 6 Feb	Team #1

C. Time your presentation to last 22 minutes, which will leave a bit of time for questions.

D. The following are organizational guidelines for your presentation:

1. Present one title slide showing the name of your project and the members of your team.
2. Present a few slides overviewing the basic project requirements (from Section 1 of the requirements document).
3. Present two slides showing the initial UI for the primary category of users, and an expansion of the command menus (from Section 2.1 of the requirements).
4. If appropriate, show additional slides of alternate initial UIs for other major categories of users (from Section 2.1).
5. Present additional screen-shot slides that show major features of your system (from Sections 2.2 and beyond).
6. Prepare additional explanatory slides to aid the presentation.
   a. You do not necessarily need a lot of explanatory slides -- you may choose to discuss system features mostly orally.
   b. If you do have explanatory slides, they should have only major points, in large text font (at least 24

points).

E. You may make your presentation electronically (e.g., Acrobat, PowerPoint, HTML) or on overhead transparencies.

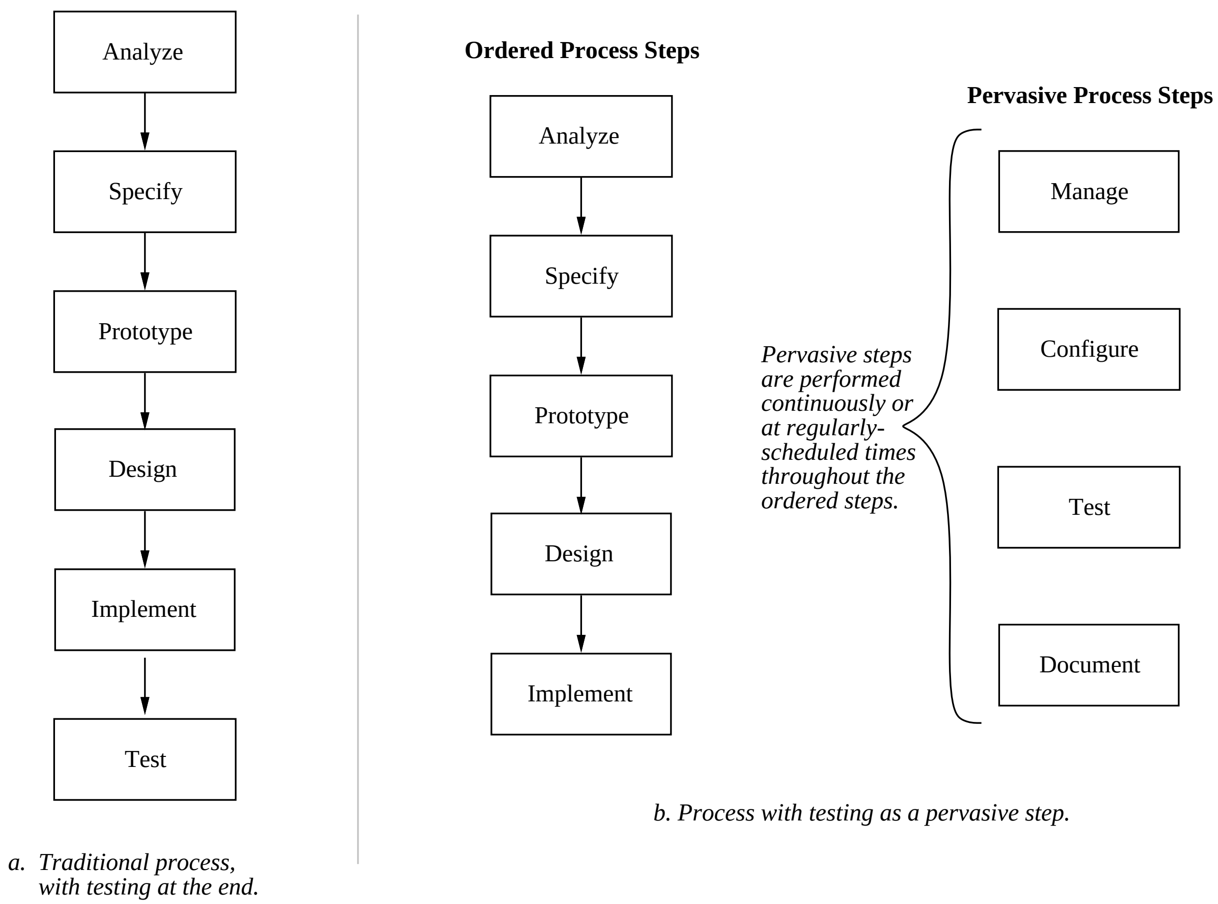
F. If you prepare your presentation in HTML, please organize it into slides, so as to avoid the distraction of jumping around in a browser during the presentation.

IV. The role of testing in the software engineering process.

A. In what might be called a traditional view of the software process, testing is seen as the last step, following implementation.

1. In this view, the program code itself is the only artifact that is subject to formal testing.
2. While code testing is critically important for quality software, the code is not the only artifact that should be tested.
3. In fact, all of the other major software process artifacts can be tested formally -- the requirements, the specification, and the design.

B. Figure 1 compares the position of testing as the final step of the process versus a pervasive step.



a. Traditional process, with testing at the end.

b. Process with testing as a pervasive step.

Figure 1: Two views of testing in the software process.

1. As discussed in Lecture Notes Week 1, pervasive steps run continuously throughout the development process, or at regularly-scheduled intervals.
2. In addition to testing, the other pervasive steps deal with management, configuration, and documentation.

C. There are three types of testing that are performed during different stages of the software process.
1. *Inspection testing* entails systematic human inspection of all levels of software artifact, from requirements through implementation.
2. *Functional testing* is performed by programmers on the executable code as it is developed.
3. *Acceptance testing* is performed by end users on the released product.

V. Inspection testing the requirements.

A. Testing with walkthroughs and reviews.
1. The purpose is the same as walkthroughs and reviews conducted during the development of just about any kind of product.
2. Namely, we want to assure that what is being developed is on track and meets customer needs.
3. Walkthroughs and reviews are an important means to "debug" the requirements.
4. Public reviews can be held at specific milestones during the course of requirements gathering and analysis.
5. Limited members of the technical staff hold detailed walkthroughs to refine requirements specifications.
6. Such walkthroughs are particularly important in the process of requirements analysis since such a wide range of people are potentially involved.
7. In 308, intra-group walkthroughs are conducted during our weekly meetings.
8. In addition, each group will gives two oral reviews to the rest of the class during in the quarter; first is in week 5 as scheduled above.

B. Formal inspection testing.
1. Starting in week 4, the functional requirements will be formally inspected by a duly appointed *inspection test engineer*.
2. During weeks 4 through 11, each group member will have a one-week assignment as the official inspection tester (see milestone 3 writeup for exact schedule, since it varies based on team size).
3. Details are in the handout entitled "Standard Operating Procedures, Volume 2: Requirements Testing"

C. Model building as a means of concept testing.
1. A common practice among engineers is to build a model of a proposed engineered artifact, to see if the high-level ideas about the artifact are sound.
2. For CSC 308, model building is done during the next ordered step of the software process after requirements analysis -- *specification*.

VI. The next major phase of the software process -- requirements modeling and formal specification.

A. The goal is to formalize the user-oriented functional requirements, so that:
1. the requirements are complete and consistent;
2. the requirements are clear and unambiguous for the system design and implementation team.

B. While fully formal modeling of software is not (yet) practiced as widely as for other forms of engineered artifacts, the utility of formal software models is substantial. Semi-formal modeling is gaining wider acceptance in the SE world.

VII. Languages to formally specify requirements.

A. Candidates include:

1. "Firmed up" English and pictures -- understandable but imprecise.
2. Semi-formal requirements specification languages -- helpful for high-level modeling, but not precise enough to ensure a complete and consistent specification.
3. Graphical notations -- helpful to clarify some aspects of a formal model, but not generally adequate for a complete specification.
4. Fully formal textual notations, including mathematics -- these remove all imprecision but are very demanding to use and understand.

B. Alas, "demanding to use and understand" is an attribute of many formal engineering notations.
1. Building and analyzing formal models is an important part of what engineers do to earn their keep.
2. Without a formal model, we run the very substantial risk of not fully understanding the system we want to build, and as a result building a faulty system.

C. Why a formal language?
1. Remove the imprecision and ambiguity of normal English prose.
2. Avoid misunderstanding among analysts and potential users -- *consistency*.
3. Provide a means to identify when the requirements analysis process is finished -- *completeness.*
4. Provide some quantifiable measures by which to judge if a delivered system actually meets the requirements -- *verifiability.*

VIII. Just how formal do we get?

A. In 308, we will go all the way down to formal mathematical logic.

B. We will do so in a sequence of steps from informal, to semi-formal, to fully formal.

C. Each step requires more work and more specialized knowledge.

D. In the real world, different participants in the analysis process will have different technical backgrounds.
1. Therefore, not all analysts will be involved with the most formal aspects of the document.
2. It is ultimately the job of the systems analyst to take input from all other analysts and produce a fully formal result.

E. Formality is particularly important in a growing number of "safety-critical" applications, such as avionics and medical systems, among others.
1. General rule -- the more important it is to prove that a computer system works properly, the more formally must it be specified.
2. Formal specification can be used in other areas that do not strictly involve safety, such as verifiably secure information processing system for financial transactions.

IX. Further details on formalizing the requirements.

A. The first step in formalizing user-oriented requirements is to build a *requirements model*.

B. The model is a more abstract representation of the requirements, written in a more formal language than English prose and pictures.

C. The objective in building the model is to depict the structure and operational behavior of a proposed system accurately and precisely.

D. Elements of the requirements model are the following:
1. The definition of *objects* upon which the system operates.
2. The definition of *operations* that the system performs.
3. The definition of object and operation *attributes*.

4. The definition of *relationships* between objects and operations.
5. *Statements of fact* about objects and operations, which statements can be validated to be true or false.
6. *Explanatory remarks* that aid in human understanding of the model.

E. The formal language we will use in 308 is Java, with modifications to make it suitable as an abstract specification language.

F. An overview is presented in the handout entitled "Java as an Abstract Modeling Language".

G. Here is a summary of using Java as abstract modeling language:

1. Objects are modeled as fully abstract Java classes or enums; no concrete classes, no interfaces.
2. Operations are modeled as method signatures; no method implementations.
3. Object attributes are modeled as Java annotations.
4. Object relationships are
   a. *has-a*, which is modeled as data fields
   b. *is-a*, which is modeled as inheritance using `extends`
5. Statements of fact are modeled with JML assertions (more on this in coming weeks)
6. The following Java features are *not used* in an abstract model:
   a. executable code
   b. information hiding with `public`, `private`, or `protected`
   c. exceptions
   d. library data structures except `Collection`
   e. primitive types except `int`, `double`, and `boolean`
   f. any other Java feature not explicitly mentioned above

X. Heuristics for deriving a requirements model from user-oriented requirements scenarios.

A. In our scenario style of requirements analysis, the requirements model is derived from the pictures of the user interface and the accompanying textual narrative.

B. The following heuristics can be used to derive an initial set of objects and operations from a graphical user interface:

1. Function buttons and menu items generally correspond to operations.
2. Data-entry screens and output screens generally correspond to objects.
3. More specifically, data-entry dialogs that appear in response to invoking an operation generally correspond to the input object(s) for the invoked operation.
4. Output reporting screens that appear in response to confirming an input dialog (E.g., with an "OK" button) generally correspond to the output object(s) for the confirmed operation.
5. Interface elements that allow entry of a single number, string, or boolean value correspond to primitive types.
6. The hierarchical structure of objects is generally displayed in the interface by nested or cascading windows and boxes, with primitive elements at the lowest level of nesting.

C. Specific details of object and operation attributes are derived from the scenario narrative that accompanies the interface pictures.

XI. Some examples from the Calendar Tool.

A. To illustrate the derivation of a requirements model, we'll apply the preceding basic heuristics to Calendar Tool example.

B. Complete details of the initial modeling for the Calendar Tool are in the specification directory of Milestone 4 example.

XII. Deriving scheduling operations.

A. Here is the top-level `Schedule` command menu from the Calendar Tool:

```
Appointment ...
Meeting ...
Task ...
Event ...
```

B. Applying the first heuristic (buttons and menus indicate operations), we can identify the following four operations from the `Schedule` menu:

```
void scheduleAppointment();
void scheduleMeeting();
void scheduleTask();
void scheduleEvent();
```

C. We have not yet identified the following aspects of these operations:

1. What class they go in.
2. What parameter(s) they take.
3. What return value, if any, they produce.

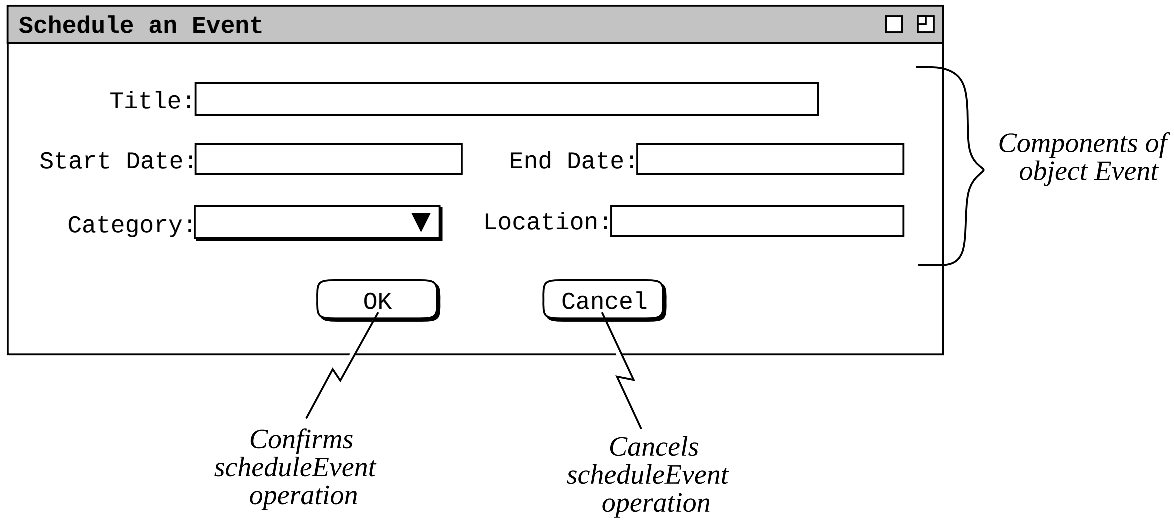
D. Linguistically, operation names should always be verbs or verb phrases.

1. Depending on how the user commands are structured, we can use different combinations of interface element names to derive meaningful operation names.
2. In this case, which is reasonably typical, we've concatenated a menu name with the name of each menu item to derive the operation names.
3. An important point is to have traceability between the terminology used in the user interface and the corresponding model.
   a. In fact, the derivation of model names can help point out flaws or inconsistencies in the interface scenarios.
   b. If it is difficult to derive a simple and meaningful name for an operation from the interface, this is a sign that the interface naming might well be improved.
   c. This is an instance of a recurring principle in requirements analysis and modeling -- "form follows function".
   d. That is, a well-defined interface scenario leads to a well-defined model, and vice versa.

XIII. Deriving scheduling objects.

A. From the second heuristic (data screens are objects), we can identify as objects each of the data-entry screens that appear in response to the user selecting one of the `Schedule` menu operations.

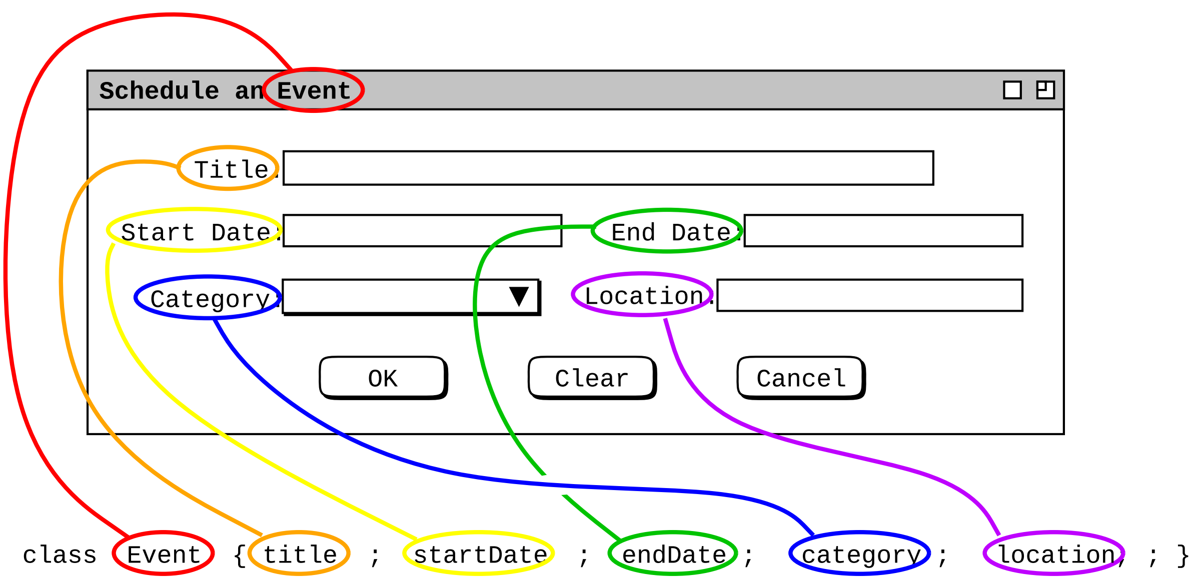
B. To start with a simple example first, let us consider the derivation of the `Event` object, from the following interface picture:



C. Applying heuristics 5 and 6, we can derive the following object definitions:

```
class Event {
    String title;
    Date startDate
    Date endDate
    Category category
    String location;
}
class Date { /* ... */ }
class Category { /* ... */ }
```

with an annotated version of the derivation looking like this:



D. In these definitions, we've done the following initial data analysis:
   1. The title and location fields are primitive string type.
   2. The other data fields are defined as object types that we've named, but not yet fully defined.

XIV. Object derivation details.

A. As discussed in the "Java as Modeling Language" handout there are only a few Java forms used to model data

B. Table 1 summarizes these, along with the common interface forms.

C. These are constructs you should be familiar with in Java.

D. The table notes common interface forms for each of the basic object types.

XV. Refining object definitions.

A. An examination of the narrative for the event dialog, indicates that the `Title` and `Location` components of an event are free-form strings, hence their definition as `String` types.

B. Java's `String` type is used to model a any free-form text string that the user may type.

C. In Milestone 4, the details of date formats has not yet been worked out.
   1. Given this, we'll leave the definitions of the `Date` class to be resolved later.
   2. I.e., we'll leave the definitions as

```
class Date { /* ... */ }
```

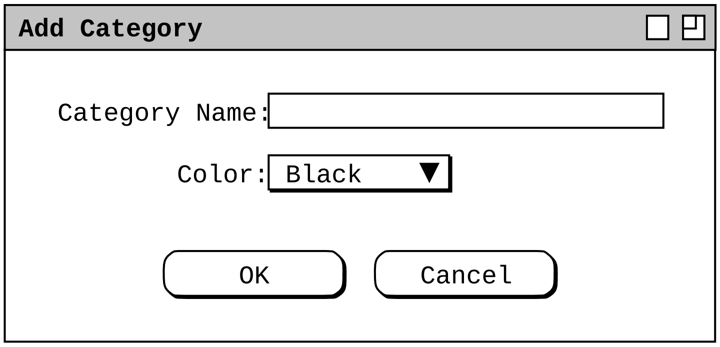
D. The user interface displays the `Category` as a list of selections.
   1. This might lead us to consider modeling the `Category` component as a list of form

```
class Category { String* list; }
```

   2. However, a more careful analysis of the requirements shows that for a given event, the `Category` component is only one of a set of possibilities.
   3. Hence, the `Category` component would not be a list, but rather just a primitive String.
   4. Further analysis of the requirements shows that a category is not just a plain string, since each category has an explicitly selected color, as shown in the add-category dialog:

Java Form	**Meaning**	**Common Interface Form**
int	numeric integer	string editor for numbers; numeric slider bar or dial
double	numeric real number	same as integer
String	free-form string value	string editor or combo box
boolean	true/false value	string editor for true/false value; on/off button
class data fields	components of the class	box containing other types
enum literals	one of a set of possibilities	radio buttons; fixed-length listing of selections
`Collection`	zero or more components of the same type	variable-length listing of data values or selections
`Method`	the type of an operation	push button or menu item

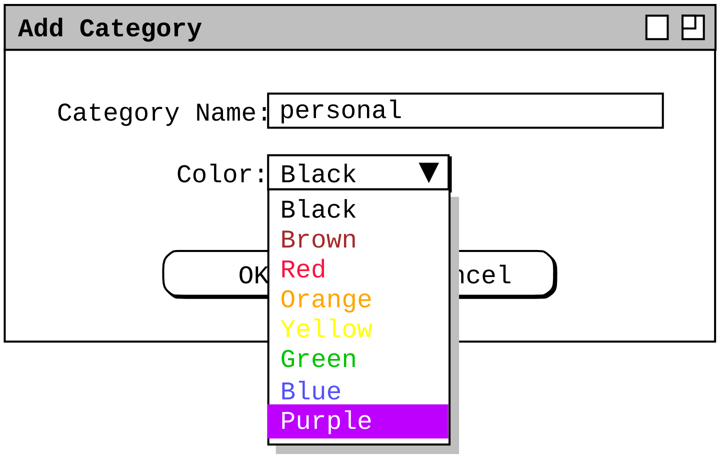
Table 1: Java Modeling Forms.



5. Hence, the most accurate definition of `Category` is

```
class Category {
    String name;
    Color color;
}
```

6. A subsequent screen shot in the scenarios shows that the `Color` component is one of a fixed set of selections:



7. Accordingly, we can model `Color` as follows:

```
enum Color {
    Black, Brown, Red, Orange, Yellow or Green, Blue, Purple;
}
```

E. The preceding analysis for deriving objects is typical in requirements modeling.

1. First we derive initial object definitions from the UI pictures.
2. Then we refine the definitions based on the scenario narrative.
3. We continue to refine until all objects are defined in terms of primitives, or we've decided to defer complete definition of model data until more requirements have been completed.

XVI. Refining operation definitions.

A. The key step in refining an operation is determining what object class it belongs in.

B. This will clarify what object is operated on.

C. In the case of the four scheduling operations, an analysis of the requirements leads us to understand that these operations work on a *Calendar* object.

D. Hence, we have the definition

```
class Calendar {
    void scheduleAppointment();
    void scheduleMeeting();
    void scheduleTask();
    void scheduleEvent();
}
```

E. Using heuristic 3 (data-entry dialogs are input objects), we refine the four scheduling operations as follows:

```
class Calendar {
    void scheduleAppointment(Appointment);
    void scheduleMeeting(Meeting);
    void scheduleTask(Task);
    void scheduleEvent(Event);
}
```

F. Since we want all of our models to compile with the Java compiler, we need to clarify that the preceding definition is intended to be an abstract model.

1. Abstract in this context means, among other things, that we leave out all operational code from the model.
2. Hence to compile in Java we must declare all of the methods to be `abstract`, as well as the class that contains these methods.

G. So, here is the compilable definition of the modeled Calendar object, along with its operations:

```
abstract class Calendar {
    abstract void scheduleAppointment(Appointment);
    abstract void scheduleMeeting(Meeting);
    abstract void scheduleTask(Task);
    abstract void scheduleEvent(Event);
}
```

XVII. Identifying collection objects.

A. A key aspect of data modeling is the identification of *collection* objects.

B. Abstractly, a collection contains zero or more objects of a particular type.

C. In terms of requirements scenarios, collections can be identified by language that describes objects with multiple entries, and operations that add entries to the collection.

D. For example, in Section 2.2 of the Calendar Tool scenarios, the following kind of language helps identify the calendar as a collection of appointments:

> *"After scheduling and confirming an appointment, the appointment data are entered in an online working copy of the user's calendar."*

E. With Java as a modeling language, we will use the `Collection` interface to model abstract collections, as in this definition of `Calendar`:

```
abstract class Calendar {
    abstract void scheduleAppointment(Appointment);
    abstract void scheduleMeeting(Meeting);
    abstract void scheduleTask(Task);
    abstract void scheduleEvent(Event);

    Collection<Appointment> data;
}
```

F. Representing a Calendar as a collection of `Appointment`s is in fact an over-simplification of a `Calendar`, since calendars can contain meetings, tasks and events, as well as appointments.

G. We'll address this issue soon, by defining a parent class for these four types of scheduled items, and representing `Calendar` data thusly:

```
Collection<ScheduledItem> data;
```

H. Another way to identify collections in requirements scenarios is by the pattern of operations that are used on collections.

1. The operations are *additive*, *destructive*, *modifying*, and *selective*.
2. In more common terms, these are operations to add, delete, edit, and find items in a collection.
3. In upcoming notes, we'll consider this to be a formal specification pattern.

XVIII. Deriving a monthly view object.

A. A significant number of objects and operations will ultimately be derived from the calendar `View` commands.

B. As an initial example, consider in Figure 2 the monthly view that is displayed in response to the user selecting the `Month` item in the `View` menu.

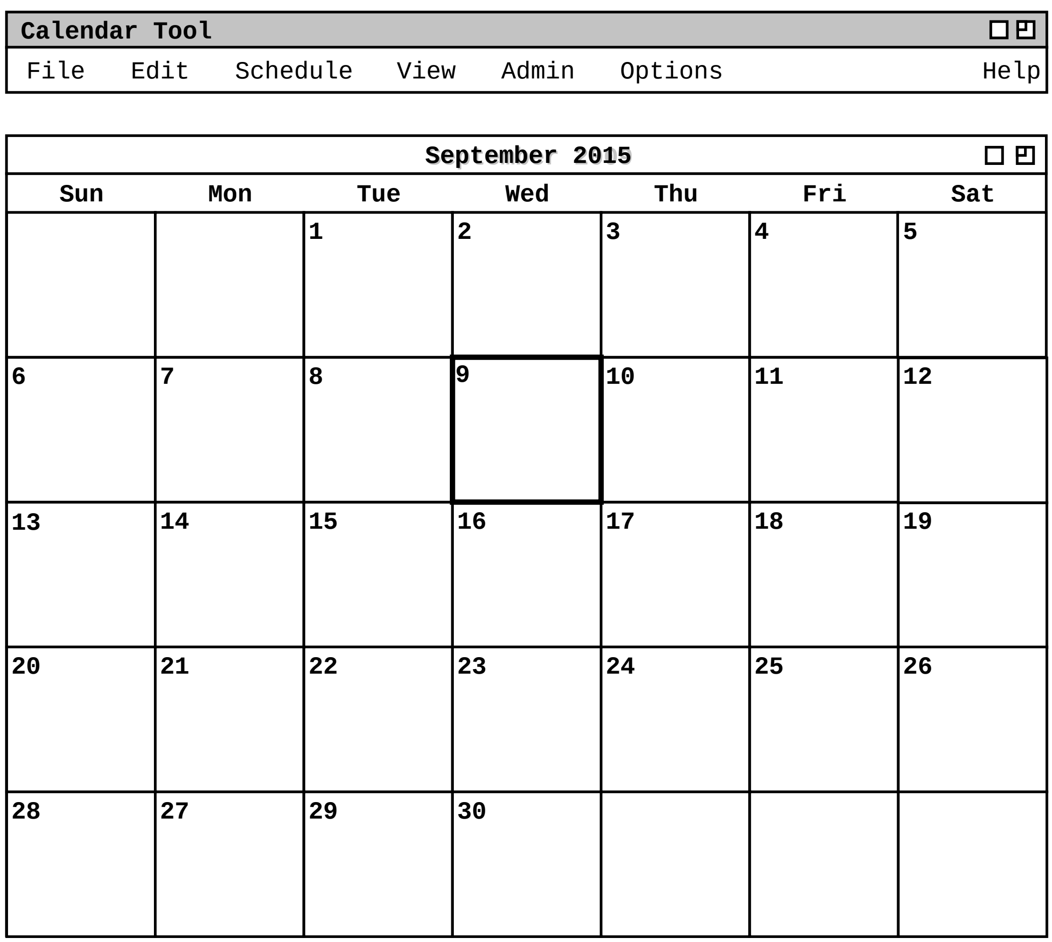


Figure 2: Monthly calendar view.

C. From this we can derive the following objects:

```
import java.util.Collection;

/**
 * A MonthlyAgenda contains a small daily view for each day of the month,
 * organized in the fashion typical in paper calendars.
 */
class MonthlyAgenda {
    FullMonthName name;
    DayOfTheWeek firstDay;
    int numberOfDays;
    Collection<SmallDayView> items;
}

class FullMonthName {
    String month;
    int year;
}

enum DayOfTheWeek { Sun, Mon, Tue, Wed, Thu, Fri, Sat }

/**
 * A SmallDayView has the number of the date and a list of zero or more short
 * item descriptions.
 */
class SmallDayView {
    int DateNumber;
    Collection<BriefItemDescription> items;
}

class BriefItemDescription {
    String title;
    Time startTime;
    Duration duration;
    Category category;
}

class Time { /* ... */ }
class Duration { /* ... */ }
class Category { /* ... */ }
```

XIX. Some observations on requirements modeling.

A. The Calendar Tool will provide some interesting examples where a model can be derived in a number of different ways.

1. For example, should the Calendar itself be modeled as a collection of scheduled items or as a collection of years?
2. Should dates be modeled as simple strings or a composite objects?
3. Which of these is the "correct" or "most accurate" way to model?

B. The general answer to such questions is that we strive to model objects and operations *as perceived by the end user*.

1. Our single criterion for model correctness and accuracy is based on how well we represent objects and operations in terms of what the user thinks.
2. What we definitely do not want to do is model things in terms of efficient computer data structures.
3. We will discuss these requirements modeling ideas more in upcoming lectures.