Writing Robust Java Code

The AmbySoft Inc. Coding Standards for Java
v17.01d

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Purpose of this White Paper

This white paper describes a collection of standards, conventions, and guidelines for writing solid Java code. They are based on sound, proven software engineering principles that lead to code that is easy to understand, to maintain, and to enhance. Furthermore, by following these coding standards your productivity as a Java developer should increase remarkably – Experience shows that by taking the time to write high-quality code right from the start you will have a much easier time modifying it during the development process. Finally, following a common set of coding standards leads to greater consistency, making teams of developers significantly more productive.

Important Features of This White Paper

- Existing standards from the industry are used wherever possible – You can reuse more than just code.
- The reasoning behind each standard is explained so that you understand why you should follow it.
- Viable alternatives, where available, are also presented along with their advantages and disadvantages so that you understand the tradeoffs that have been made.
- The standards presented in this white paper are based on real-world experience from numerous object-oriented development projects. This stuff works in practice, not just theory.
- These standards are based on proven software-engineering principles that lead to improved development productivity, greater maintainability, and greater enhancability.

Target Audience

Professional software developers who are interested in:

- Writing Java code that is easy to maintain and to enhance
- Increasing their productivity
- Working as productive members of a Java development team

Help Me Improve These Standards

Because I welcome your input and feedback, please feel free to email me at scott@ambysoft.com with your comments and suggestions. Let's work together and learn from one another.

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Table of Contents

1. GENERAL CONCEPTS....1

1.1 WHY CODING STANDARDS ARE IMPORTANT....1
1.2 THE PRIME DIRECTIVE....1
1.3 WHAT MAKES UP A GOOD NAME....2
1.4 GOOD DOCUMENTATION....3
1.4.1 The Three Types of Java Comments....4
1.4.2 A Quick Overview of javadoc....5
1.5 AMBLER'S LAW OF STANDARDS....6

2. STANDARDS FOR MEMBER FUNCTIONS....7

2.1 NAMING MEMBER FUNCTIONS....7
2.1.1 Naming Accessor Member Functions....7
2.1.1.1 Getters....7
2.1.1.1.1 Alternative Naming Convention for Getters – Has and Can....8
2.1.1.2 Setters....8
2.1.1.3 Constructors....8
2.2 MEMBER FUNCTION VISIBILITY....9
2.3 DOCUMENTING MEMBER FUNCTIONS....9
2.3.1 The Member Function Header....9
2.3.2 Internal Documentation....11
2.4 TECHNIQUES FOR WRITING CLEAN CODE....12
2.4.1 Document Your Code....12
2.4.2 Paragraph/Indent Your Code....13
2.4.3 Paragraph and Punctuate Multi-Line Statements....13
2.4.4 Use Whitespace in Your Code....14
2.4.5 Follow The Thirty-Second Rule....14
2.4.6 Write Short, Single Command Lines....14
2.4.7 Specify the Order of Operations....14
2.5 JAVA CODING TIPS....15
2.5.1 Organize Your Code Sensibly....15
2.5.2 Place Constants on the Left Side of Comparisons....15

3. STANDARDS FOR FIELDS (ATTRIBUTES/PROPERTIES)....16

3.1 NAMING FIELDS....16
3.1.1 Use a Full English Descriptor for Field Names....16
3.1.1.1 Alternative – Hungarian Notation....16
3.1.1.2 Alternative – Leading or Trailing Underscores....17
3.1.2 Naming Components (Widgets)....17
3.1.2.1 Alternative for Naming Components – Hungarian Notation....17
3.1.2.2 Alternative for Naming Components – Postfix-Hungarian Notation....17
3.1.3 Naming Constants....18
3.1.4 Naming Collections....19
3.1.4.1 Alternative for Naming Collections – The 'Some' Approach....19
3.1.5 Do Not "Hide" Names....19
3.2 FIELD VISIBILITY....20
3.3 DOCUMENTING A FIELD....21
3.4 THE USE OF ACCESSOR MEMBER FUNCTIONS....21
3.4.1 Naming Accessors....22
3.4.2 Advanced Techniques for Accessors....23
3.4.2.1 Lazy Initialization....23

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3.4.2.2 Getters for Constants 24
3.4.2.3 Accessors for Collections 26
3.4.2.4 Accessing Several Fields Simultaneously 26
3.4.3 Visibility of Accessors 27
3.4.4 Why Use Accessors? 28
3.4.5 Why Shouldn't You Use Accessors? 28
3.5 ALWAYS INITIALIZE STATIC FIELDS 29

4. STANDARDS FOR LOCAL VARIABLES 30

4.1 NAMING LOCAL VARIABLES 30
4.1.1 Naming Streams 30
4.1.2 Naming Loop Counters 30
4.1.3 Naming Exception Objects 31
4.1.4 Bad Ideas for Naming Local Variables 31
4.2 DECLARING AND DOCUMENTING LOCAL VARIABLES 32
4.2.1 General Comments About Declaration 32

5. STANDARDS FOR PARAMETERS (ARGUMENTS) TO MEMBER FUNCTIONS 33

5.1 NAMING PARAMETERS 33
5.1.1 Alternative – Prefix Parameter Names with 'a' or 'an' 33
5.1.2 Alternative – Name Parameters Based on Their Type 33
5.1.3 Alternative – Name Parameters The Same as Their Corresponding Fields (if any) 34
5.2 DOCUMENTING PARAMETERS 34

6. STANDARDS FOR CLASSES, INTERFACES, PACKAGES, AND COMPILATION UNITS 35

6.1 STANDARDS FOR CLASSES 35
6.1.1 Class Visibility 35
6.1.2 Naming Classes 35
6.1.3 Documenting a Class 36
6.1.4 Class Declarations 37
6.1.4.1 Apply The "final" Keyword Sensibly 37
6.1.4.2 Ordering Member Functions and Fields 37
6.1.5 Minimize the Public and Protected Interface 38
6.2 STANDARDS FOR INTERFACES 39
6.2.1 Naming Interfaces 39
6.2.2 Documenting Interfaces 39
6.3 STANDARDS FOR PACKAGES 40
6.3.1 Naming Packages 40
6.3.2 Documenting a Package 40
6.4 STANDARDS FOR COMPILATION UNITS 41
6.4.1 Naming a Compilation Unit 41
6.4.2 Documenting a Compilation Unit 41

7. MISCELLANEOUS STANDARDS/ISSUES 42

7.1 REUSE 42
7.2 USE WILD CARDS WHEN IMPORTING CLASSES 42
7.2.1 Alternative – Explicitly Specify Each Imported Class 42
7.3 OPTIMIZING JAVA CODE 43
7.4 WRITING JAVA TEST HARNESSES 46

8. THE SECRETS OF SUCCESS 47

8.1 USING THESE STANDARDS EFFECTIVELY 47
8.2 OTHER FACTORS THAT LEAD TO SUCCESSFUL CODE 48

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9. PROPOSED JAVADOC TAGS FOR MEMBER FUNCTIONS 50

10. WHERE TO GO FROM HERE....................51

10.1 CREATING YOUR OWN INTERNAL CORPORATE GUIDELINES?.................... 51

10.1.1 Using This PDF File....................51

10.1.2 Obtaining the Source Document for This File....................51

11. SUMMARY....................52

11.1 JAVA NAMING CONVENTIONS.................... 53

11.2 JAVA DOCUMENTATION CONVENTIONS.................... 55

11.2.1 Java Comment Types....................55

11.2.2 What To Document....................56

11.3 JAVA CODING CONVENTIONS (GENERAL).................... 57

GLOSSARY....................58

REFERENCES AND SUGGESTED READING....................62

12. ABOUT THE AUTHOR....................64

13. INDEX....................65

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1. General Concepts

I'd like to start this white paper with a discussion of some general concepts that I feel are important for coding standards. I begin with the importance of coding standards, propose the "Prime Directive" for standards, and then follow with the factors that lead to good names and good documentation. This section will set the stage for the rest of this white paper, which covers standards and guidelines for Java coding.

1.1 Why Coding Standards are Important

Coding standards for Java are important because they lead to greater consistency within your code and the code of your teammates. Greater consistency leads to code that is easier to understand, which in turn means it is easier to develop and to maintain. This reduces the overall cost of the applications that you create.

You have to remember that your Java code will exist for a long time, long after you have moved on to other projects. An important goal during development is to ensure that you can transition your work to another developer, or to another team of developers, so that they can continue to maintain and enhance your work without having to invest an unreasonable effort to understand your code. Code that is difficult to understand runs the risk of being scrapped and rewritten – I wouldn't be proud of the fact that my code needed to be rewritten, would you? If everyone is doing their own thing then it makes it very difficult to share code between developers, raising the cost of development and maintenance.

Inexperienced developers, and cowboys who do not know any better, will often fight having to follow standards. They claim they can code faster if they do it their own way. Pure hogwash. They MIGHT be able to get code out the door faster, but I doubt it. Cowboy programmers get hung up during testing when several difficult-to-find bugs crop up, and when their code needs to be enhanced it often leads to a major rewrite by them because they're the only ones who understand their code. Is this the way that you want to operate? I certainly do not.

1.2 The Prime Directive

No standard is perfect and no standard is applicable to all situations: sometimes you find yourself in a situation where one or more standards do not apply. This leads me to introduce what I consider to be the prime directive of standards:

> **When you go against a standard, document it.** All standards, except for this one, can be broken. If you do so, you must document why you broke the standard, the potential implications of breaking the standard, and any conditions that may/must occur before the standard can be applied to this situation.

The bottom line is that you need to understand each standard, understand when to apply them, and just as importantly when not to apply them.

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1.3 What Makes Up a Good Name

We will be discussing naming conventions throughout the standards, so let's set the stage with a few basics:

1. **Use full English descriptors[1] that accurately describe the variable/field/class/…** For example, use names like **firstName**, **grandTotal**, or **CorporateCustomer**. Although names like **x1**, **y1**, or **fn** are easy to type because they're short, they do not provide any indication of what they represent and result in code that is difficult to understand, maintain, and enhance (Nagler, 1995; Ambler, 1998a).

2. **Use terminology applicable to the domain.** If your users refer to their clients as customers, then use the term **Customer** for the class, not **Client**. Many developers will make the mistake of creating generic terms for concepts when perfectly good terms already exist in the industry/domain.

3. **Use mixed case to make names readable.** You should use lower case letters in general, but capitalize the first letter of class names and interface names, as well as the first letter of any non-initial word (Kanerva, 1997).

4. **Use abbreviations sparingly, but if you do so then use them intelligently.** This means you should maintain a list of standard short forms (abbreviations), you should choose them wisely, and you should use them consistently. For example, if you want to use a short form for the word "number," then choose one of **nbr**, **no**, or **num**, document which one you chose (it doesn't really matter which one), and use only that one.

5. **Avoid long names (< 15 characters is a good idea).** Although the class name **PhysicalOrVirtualProductOrService** might seem to be a good class name at the time (OK, I'm stretching it on this example) this name is simply too long and you should consider renaming it to something shorter, perhaps something like **Offering** (NPS, 1996).

6. **Avoid names that are similar or differ only in case.** For example, the variable names **persistentObject** and **persistentObjects** should not be used together, nor should **anSqlDatabase** and **anSQLDatabase** (NPS, 1996).

7. **Capitalize the first letter of standard acronyms**. Names will often contain standard abbreviations, such as SQL for Standard Query Language. Names such as **sqlDatabase** for an attribute, or **SqlDatabase** for a class, are easier to read than **sQLDatabase** and **SQLDatabase**.

[1] I use the term "full English descriptor" throughout this document, but what I really mean is "full [insert your language here] descriptor", so if the spoken language of your team is French then use full French descriptors everywhere.

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1.4 Good Documentation

We will also be discussing documentation conventions, so let's discuss some of the basics first:

1. **Comments should add to the clarity of your code.** The reason why you document your code is to make it more understandable to you, your coworkers, and to any other developer who comes after you (Nagler, 1995).

2. **If your program isn't worth documenting, it probably isn't worth running (Nagler, 1995).** What can I say, Nagler hit the nail on the head with this one.

3. **Avoid decoration, i.e. do not use banner-like comments.** In the 1960s and 1970s COBOL programmers got into the habit of drawing boxes, typically with asterisks, around their internal comments (NPS, 1996). Sure, it gave them an outlet for their artistic urges, but frankly it was a major waste of time that added little value to the end product. You want to write clean code, not pretty code. Furthermore, because many of the fonts used to display and print your code are proportional, and many aren't, you can't line up your boxes properly anyway.

4. **Keep comments simple.** Some of the best comments I have ever seen are simple, point-form notes. You do not have to write a book, you just have to provide enough information so that others can understand your code.

5. **Write the documentation before you write the code.** The best way to document code is to write the comments before you write the code. This gives you an opportunity to think about how the code will work before you write it and will ensure that the documentation gets written. Alternatively, you should at least document your code as you write it. Because documentation makes your code easier to understand you are able to take advantage of this fact while you are developing it. The way I look at it, if you are going to invest the time writing documentation you should at least get something out of it (Ambler, 1998a).

6. **Document why something is being done, not just what.** Fundamentally, I can always look at a piece of code and figure out what it does. For example, I can look at the code in Example 1 below and figure out that a 5% discount is being given on orders of $1,000 dollars or more. Why is this being done? Is there a business rule that says that large orders get a discount? Is there a limited-time special on large orders or is it a permanent program? Was the original programmer just being generous? I do not know unless it is documented somewhere, either in the source code itself or in an external document (Ambler, 1998a).

```
if ( grandTotal >= 1000.00)
{
        grandTotal = grandTotal * 0.95;
}
```

Example 1.1

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1.4.1 The Three Types of Java Comments

Java has three styles of comments: Documentation comments start with /** and end with */, C-style comments which start with /* and end with */, and single-line comments that start with // and go until the end of the source-code line. In the chart below is a summary of my suggested use for each type of comment, as well as several examples.

Comment Type	Usage	Example
Documentation	Use documentation comments immediately before declarations of interfaces, classes, member functions, and fields to document them. Documentation comments are processed by *javadoc*, see below, to create external documentation for a class.	/** Customer – A customer is any person or organization that we sell services and products to. @author S.W. Ambler */
C style	Use C-style comments to document out lines of code that are no longer applicable, but that you want to keep just in case your users change their minds, or because you want to temporarily turn it off while debugging.	/* This code was commented out by J.T. Kirk on Dec 9, 1997 because it was replaced by the preceding code. Delete it after two years if it is still not applicable. . . . (the source code) */

Single line	Use single line comments internally within member functions to document business logic, sections of code, and declarations of temporary variables.	// Apply a 5% discount to all invoices
		// over $1000 as defined by the Sarek
		// generosity campaign started in
		// Feb. of 1995.

The important thing is that your organization should set a standard as to how C-style comments and single-line comments are to be used, and then to follow that standard consistently. Use one type to document business logic and use the other to document out old code. I prefer using single-line comments for business logic because I can put the documentation on the same line as the code (this is called endlining and sometimes inlining). I then use C-style comments for documenting out old code because I can comment out several lines at once and because C-style looks very similar to documentation comments I rarely use them so as to avoid confusion.

Tip – Beware Endline Comments

McConnell (1993) argues strongly against the use of endline comments, also known as inline comments or end of line comments. He points out that the comments have to be aligned to the right of the code so that they do not interfere with the visual structure of the code. As a result they tend to be hard to format, and that "if you use many of them, it takes time to align them. Such time is not spent learning more about the code; it is dedicated solely to the tedious task of pressing the spacebar or the tab key." He also points out that endline comments are also hard to maintain because when the code on the line grows it bumps the endline comment out, and that if you are aligning them you have to do the same for the rest of them. My advice, however, is to not waste your time aligning endline comments.

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1.4.2 A Quick Overview of javadoc

Included in Sun's Java Development Kit (JDK) is a program called *javadoc* that processes Java code files and produces external documentation, in the form of HTML files, for your Java programs. I think that *javadoc* is a great utility, but at the time of this writing it does have its limitations. First, it supports a limited number of tags, reserved words that mark the beginning of a documentation section. The existing tags are a very good start but I feel are not sufficient for adequately documenting your code. I'll expand upon this statement later. For now, I present a brief overview of the current *javadoc* tags in the chart below, and will refer you to the JDK *javadoc* documentation for further details.

Tag	Used for	Purpose
@author name	Interfaces, Classes, Interfaces	Indicates the author(s) of a given piece of code. One tag per author should be used.
@deprecated	Interfaces, Classes, Member Functions	Indicates that the API for the class… has been deprecated and therefore should not be used any more.
@exception name description	Member Functions	Describes the exceptions that a member function throws. You should use one tag per exception and give the full class name for the exception.
@param name description	Member Functions	Used to describe a parameter passed to a member function, including its type/class and its usage. Use one tag per parameter.
@return description	Member Functions	Describes the return value, if any, of a member function. You should indicate the type/class and the potential use(s) of the return value.
@since	Interfaces, Classes, Member Functions	Indicates how long the item has existed, i.e. since JDK 1.1
@see ClassName	Classes, Interfaces, Member Functions, Fields	Generates a hypertext link in the documentation to the specified class. You can, and probably should, use a fully qualified class name.
@see ClassName#member functionName	Classes, Interfaces, Member Functions, Fields	Generates a hypertext link in the documentation to the specified member function. You can, and probably should, use a fully qualified class name.
@version text	Classes, Interfaces	Indicates the version information for a given piece of code.

The way that you document your code has a huge impact both on your own productivity and on the productivity of everyone else who later maintains and enhances it. By documenting your code early in the development process you become more productive because it forces you to think through your logic before you commit it to code. Furthermore, when you revisit code that you wrote days or weeks earlier you can easily determine what you were thinking when you wrote it – it is documented for you already.

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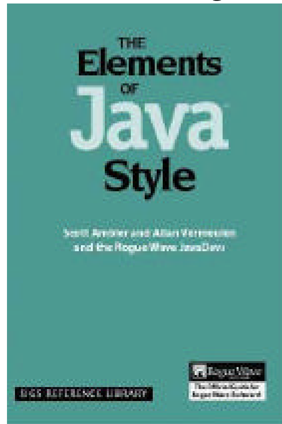
1.5 Ambler's Law of Standards

Whenever possible, reuse standards and guidelines, don't reinvent them. The greater the scope of the standards and guidelines the more desirable they are, industry standards are more desirable than organizational standards which in turn are more desirable than project standards. Projects aren't developed in a vacuum and organizations do not operate in a vacuum either, therefore the greater the scope of the standard the greater the chance that somebody else is also following it, making it that much easier for you to work together with them.

Ambler's Law of Standards

Industry standards > organizational standards > project standards > personal standards > no standards

Blatant Advertising – Purchase *The Elements of Java Style* today!



This book (Vermeulen et. al., 2000) presents a collection of strategies for writing superior Java source code. This book presents a wider range of guidelines than what is presented here in this paper, and more importantly presents excellent source code examples. It covers many topics that are not covered in this paper, such as type safety issues, exception handling, assertions, and concurrency issues such as synchronization. This paper was combined with Rogue Wave's internal coding standards and then together were evolved to become *The Elements of Java Style*, so you should find the book to be an excellent next step in your Java learning process. Visit http://www.ambysoft.com/elementsJavaStyle.html for more details.

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2. Standards For Member Functions

I'm a firm believer in maximizing the productivity of systems professionals. Because I also recognize that an application spends the majority of its existence being maintained, not developed, I am very interested in anything that can help to make my code easier to maintain and to enhance, as well as to develop. Never forget that the code that you write today may still be in use many years from now and will likely be maintained and enhanced by somebody other than you. You must strive to make your code as "clean" and understandable as possible, because these factors make it easier to maintain and to enhance.

In this section we will concentrate on four topics:
- Naming conventions
- Visibility
- Documentation conventions
- Techniques for writing clean Java code

2.1 Naming Member Functions

Member Functions should be named using a full English description, using mixed case with the first letter of any non-initial word capitalized. It is also common practice for the first word of a member function name to be a strong, active verb.

Examples:

openAccount()
printMailingLabel()
save()
delete()

This convention results in member functions whose purpose can often be determined just by looking at its name. Although this convention results in a little extra typing by the developer, because it often results in longer names, this is more than made up for by the increased understandability of your code.

2.1.1 Naming Accessor Member Functions

We will discuss accessors, member functions that get and set the values of fields (fields/properties) in greater detail in chapter 3. The naming conventions for accessors, however, are summarized below.

2.1.1.1 Getters

Getters are member functions that return the value of a field. You should prefix the word 'get' to the name of the field, unless it is a boolean field and then you prefix 'is' to the name of the field instead of 'get.'

Examples:

getFirstName()
getAccountNumber()
getLostEh()
isPersistent()
isAtEnd()

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By following this naming convention you make it obvious that a member function returns a field of an object, and for boolean getters you make it obvious that it returns true or false. Another advantage of this standard is that it follows the naming conventions used by the beans development kit (BDK) for getter member functions (DeSoto, 1997). The main disadvantage is that 'get' is superfluous, requiring extra typing.

2.1.1.1.1 Alternative Naming Convention for Getters – Has and Can

A viable alternative, based on proper English conventions, is to use the prefix 'has' or 'can' instead of 'is' for boolean getters. For example, getter names such as **hasDependents()** and **canPrint()** make a lot of sense when you are reading the code. The problem with this approach is that the BDK will not pick up on this naming strategy (yet). You could rename these member functions **isBurdenedWithDependents()** and **isPrintable()**. ☺

2.1.1.2 Setters

Setters, also known as mutators, are member functions that modify the values of a field. You should prefix the word 'set' to the name of the field, regardless of the field type.

Examples:

setFirstName(String aName)
setAccountNumber(int anAccountNumber)
setReasonableGoals(Vector newGoals)
setPersistent(boolean isPersistent)
setAtEnd(boolean isAtEnd)

Following this naming convention you make it obvious that a member function sets the value of a field of an object. Another advantage of this standard is that it follows the naming conventions used by the beans development kit (BDK) for setter member functions (DeSoto, 1997). The main disadvantage is that 'set' is superfluous, requiring extra typing.

2.1.1.3 Constructors

Constructors are member functions that perform any necessary initialization when an object is first created. Constructors are always given the same name as their class. For example, a constructor for the class **Customer** would be **Customer()**. Note that the same case is used.

Examples:

Customer()
SavingsAccount()
PersistenceBroker()

This naming convention is set by Sun and must be strictly adhered to.

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2.2 Member Function Visibility

For a good design where you minimize the coupling between classes, the general rule of thumb is to be as restrictive as possible when setting the visibility of a member function. If member function doesn't have to be public then make it protected, and if it doesn't have to be protected then make it private.

Visibility	Description	Proper Usage
public	A public member function can be invoked by any other member function in any other object or class.	When the member function must be accessible by objects and classes outside of the class hierarchy in which the member function is defined.
protected	A protected member function can be invoked by any member function in the class in which it is defined or any subclasses of that class.	When the member function provides behavior that is needed internally within the class hierarchy but not externally.
private	A private member function can only be invoked by other member functions in the class in which it is defined, but not in the subclasses.	When the member function provides behavior that is specific to the class. Private member functions are often the result of refactoring, also known as reorganizing, the behavior of other member functions within the class to encapsulate one specific behavior.
	No visibility is indicated. This is called default or package visibility, and is sometimes referred to as friendly visibility. The member function is effectively public to all other classes within the same package, but private to classes external to the package.	This is an interesting feature, but be careful with its use. I use it when I'm building domain components (Ambler, 1998b), collections of classes that implement a cohesive business concept such as "Customer", to restrict access to only the classes within the component/package.

2.3 Documenting Member Functions

The manner in which you document a member function will often be the deciding factor as to whether or not it is understandable, and therefore maintainable and extensible.

2.3.1 The Member Function Header

Every Java member function should include some sort of header, called member function documentation, at the top of the source code that documents all of the information that is critical to understanding it. This information includes, but is not limited to the following:

1. **What and why the member function does what it does**. By documenting what a member function does you make it easier for others to determine if they can reuse your code. Documenting why it does something makes it easier for others to put your code into context. You also make it easier for others to determine whether or not a new change should actually be made to a piece of code (perhaps the reason for the new change conflicts with the reason why the code was written in the first place).

2. **What a member function must be passed as parameters**. You also need to indicate what parameters, if any, must be passed to a member function and how they will be used. This information is needed so

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that other programmers know what information to pass to a member function. The *javadoc @param* tag, discussed in section 1.4.2, is used for this.

3. **What a member function returns**. You need to document what, if anything, a member function returns so that other programmers can use the return value/object appropriately. The *javadoc @return* tag, discussed in section 1.4.2, is used for this.

4. **Known bugs.** Any outstanding problems with a member function should be documented so that other developers understand the weaknesses/difficulties with the member function. If a given bug is applicable to more than one member function within a class, then it should be documented for the class instead.

5. **Any exceptions that a member function throws.** You should document any and all exceptions that a member function throws so that other programmers know what their code will need to catch. The *javadoc @exception* tag, discussed in section 1.4.2, is used for this.

6. **Visibility decisions.** If you feel that your choice of visibility for a member function will be questioned by other developers, perhaps you've made a member function public even though no other objects invoke the member function yet, then you should document your decision. This will help to make your thinking clear to other developers so that they do not waste time worrying about why you did something questionable.

7. **How a member function changes the object**. If a member function changes an object, for example the **withdraw()** member function of a bank account modifies the account balance then this needs to be indicated. This information is needed so that other Java programmers know exactly how a member function invocation will affect the target object.

8. **Include a history of any code changes**. Whenever a change is made to a member function you should document when the change was made, who made it, why it was made, who requested the change, who tested the change, and when it was tested and approved to be put into production. This history information is critical for the future maintenance programmers who are responsible for modifying and enhancing the code. *Note: This information really belongs in your software configuration management/version control system, not the source code itself! If you aren't using these sorts of tools (and you really should) then put this information into your code.*

9. **Examples of how to invoke the member function if appropriate**. One of the easiest ways to determine how a piece of code works it to look at an example. Consider including an example or two of how to invoke a member function.

10. **Applicable preconditions and postconditions**. A precondition is a constraint under which a member function will function properly, and a postcondition is a property or assertion that will be true after a member function is finished running (Meyer, 1988). In many ways preconditions and postconditions describe the assumptions that you have made when writing a member function (Ambler, 1998a), defining exactly the boundaries of how a member function is used.

11. **All concurrency issues.** Concurrency is a new and complex concept for many developers and at best it is an old and complex topic for experienced concurrent programmers. The end result is that if you use the concurrent programming features of Java then you need to document it thoroughly. Lea (1997) suggests that when a class includes both synchronized and unsynchronized member functions you must document the execution context that a member function relies on, especially when it requires unrestricted access so that other developers can use your member functions safely. When a setter, a member function that updates a field, of a class that implements the **Runnable** interface is not synchronized then you should document your reason(s) why. Finally, if you override or overload a member function and change its synchronization you should also document why.

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The important thing is that you should document something only when it adds to the clarity of your code. You wouldn't document all of the factors described above for each and every member function because not all factors are applicable to every member function. You would however document several of them for each member function that you write. In chapter 9, I propose several new documentation tags for *javadoc* to support the factors listed above.

2.3.2 Internal Documentation

In addition to the member function documentation, you also need to include comments within your member functions to describe your work. The goal is to make your member function easier to understand, to maintain, and to enhance.

There are two types of comments that you should use to document the internals of your code: C-style comments (/* … */) and single-line comments (//). As discussed in section 1.4.1, you should seriously consider choosing one style of comments for documenting the business logic of your code and one for commenting out unneeded code. My suggestion is to use single-line comments for your business logic, because you can use this style of comments both for full comment lines and for endline comments that follow at the end of a line of code. I use C-style comments to document out lines of unneeded code because I can easily take out several lines with only one comment. Furthermore, because C-style comments look so much like documentation comments I feel that their use can be confusing, taking away from the understandability of my code. Therefore I use them sparingly.

Internally, you should always document:

1. **Control structures.** Describe what each control structure does, such as comparison statements and loops. You shouldn't have to read all the code in a control structure to determine what it does, instead you should just have to look at a one or two line comment immediately preceding it.

2. **Why, as well as what, the code does.** You can always look at a piece of code and figure out what it does, but for code that isn't obvious you can rarely determine why it is done that way. For example, you can look at a line of code and easily determine that a 5% discount is being applied to the total of an order. That is easy. What isn't easy is figuring out WHY that discount is being applied. Obviously there is some sort of business rule that says to apply the discount, so that business rule should at least be referred to in your code so that other developers can understand why your code does what it does.

3. **Local variables.** Although we will discuss this in greater detail in chapter 4, each local variable defined in a member function should be declared on its own line of code and should usually have an endline comment describing its use.

4. **Difficult or complex code.** If you find that you either can't rewrite it, or do not have the time, then you must document thoroughly any complex code in a member function. My general rule of thumb is that if your code isn't obvious, then you need to document it.

5. **The processing order.** If there are statements in your code that must be executed in a defined order then you should ensure that this fact gets documented (Ambler, 1998a). There's nothing worse than making a simple modification to a piece of code only to find that it no longer works, then spending hours looking for the problem only to find that you've gotten things out of order.

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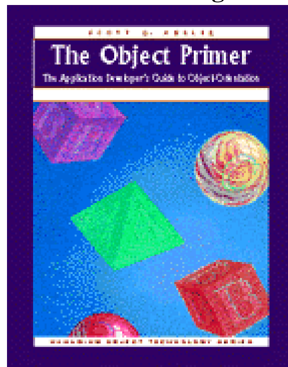
Tip – Document Your Closing Braces

Every so often you will find that you have control structures within control structures within control structures. Although you should avoid writing code like this, sometimes you find that it is better to write it this way. The problem is that it becomes confusing which ending brace, the } character, belongs to which control structure. The good news is that some code editors support a feature that when you select a open brace it will automatically highlight the corresponding closing one, the bad news is that not every editor supports this. I have found that by marking the ending braces with an endline comment such as **//end if**, **//end for**, **//end switch**, … makes my code easier to understand.

Given the choice, however, I would rather use a more sophisticated editor.

Blatant Advertising – Purchase *The Object Primer, 2nd Edition* (late Spring of 2000)!



The Object Primer is a straightforward, easy to understand introduction to object-oriented concepts, requirements, analysis, and design techniques applying the techniques of the Unified Modeling Language (UML). The Object Primer goes further to show you how to move from object modeling to object-oriented programming, providing Java examples, and describes the techniques of the Full Lifecycle Object-Oriented Testing (FLOOT) methodology to enable you to test all of your development artifacts. It also puts this material in the context of the leading software processes, including the enhanced lifecycle for the Unified Process, the process patterns of the Object-Oriented Software Process (OOSP), and the best practices Extreme Programming (XP). Visit http://www.ambysoft.com/theObjectPrimer.html for more details.

2.4 Techniques for Writing Clean Code

In this section we will cover several techniques that help to separate the professional developers from the hack coders. These techniques are:

- Document your code
- Paragraph your code
- Paragraph and punctuate multi-line statements
- Use whitespace
- Follow the thirty-second rule
- Specify the order of message sends
- Write short, single command lines

2.4.1 Document Your Code

Remember, if your code isn't worth documenting then it isn't worth keeping (Nagler, 1995). When you apply the documentation standards and guidelines proposed in this paper appropriately you can greatly enhance the quality of your code.

2.4.2 Paragraph/Indent Your Code

One way to improve the readability of a member function is to paragraph it, or in other words indent your code within the scope of a code block. Any code within braces, the **{** and **}** characters, forms a block. The basic idea is that the code within a block should be uniformly indented one unit[2]. To ensure consistency, start your member function and class declarations in column 1 (NPS, 1996).

The Java convention appears to be that the open brace is to be put on the line following the owner of the block and that the closing brace should be indented one level. The important thing as pointed out by Laffra (1997) is that your organization chooses an indentation style and sticks to it. My advice is to use the same indentation style that your Java development environment uses for the code that it generates.

2.4.3 Paragraph and Punctuate Multi-Line Statements

A related issue to paragraphing your code occurs when a single statement requires several lines of code, an example of which appears below.

Example:

```
	BankAccount newPersonalAccount = AccountFactory
		createBankAccountFor( currentCustomer, startDate,
		initialDeposit, branch);
```

Notice how I indent the second and third lines one unit, visibly indicating that they are still a part of the preceding line. Also notice how the final comma in the second line immediately follows the parameter and is not shown on the following line (word processors work this way too).

[2] There seems to be a debate raging about what a unit is, but the only unit that makes sense to me is a horizontal tab. It requires the least amount of typing, one entire keystroke, while at the same time providing enough of an indent to be noticeable. I have always found that using spaces is problematic, some people use two, some three, some four, and so on. Tabs are much easier. I have been informed that some editors convert tabs to spaces (yuck!) and that others do not support tabs at all. My only response is to invest in a decent code editor.

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2.4.4 Use Whitespace in Your Code

A few blank lines or spaces, called whitespace, added to your Java code can help to make it much more readable by breaking it up into small, easy-to-digest sections (NPS, 1996; Ambler, 1998a). The Vision 2000 team (1996) suggests using a single blank line to separate logical groups of code, such as control structures, with two blank lines to separate member function definitions. Without whitespace it is very difficult to read and to understand. In the code below notice how the readability second version of the code is improved by the addition of a blank line between setting the counter and the lines of code to calculate the grand total. Also notice how the addition of spaces around the operators and after the comma also increase the readability of the code. Small things, yes, but it can still make a big difference.

Code examples:

```
counter=1;
grandTotal=invoice.total()+getAmountDue();
grandTotal=Discounter.discount(grandTotal,this);
```

```
counter = 1;

grandTotal = invoice.total() + getAmountDue();
grandTotal = Discounter.discount(grandTotal, this);
```

2.4.5 Follow The Thirty-Second Rule

I have always believed that another programmer should be able to look at your member function and be able to fully understand what it does, why it does it, and how it does it in less than 30 seconds. If he or she can't then your code is too difficult to maintain and should be improved. Thirty seconds, that's it. A good rule of thumb suggested by Stephan Marceau is that if a member function is more than a screen then it is probably too long.

2.4.6 Write Short, Single Command Lines

Your code should do one thing per line (Vision, 1996; Ambler, 1998a). Back in the days of punch cards it made sense to try to get as much functionality as possible on a single line of code, but considering it has been over fifteen years since I have even seen a punch card I think we can safely rethink this approach to writing code. Whenever you attempt to do more than one thing on a single line of code you make it harder to understand. Why do this? We want to make our code easier to understand so that it is easier to maintain and enhance. Just like a member function should do one thing and one thing only, you should only do one thing on a single line of code. Furthermore, you should write code that remains visible on the screen (Vision, 1996). My general rule of thumb is that you shouldn't have to scroll your editing window to the right to read the entire line of code, including code that uses endline comments.

2.4.7 Specify the Order of Operations

A really easy way to improve the understandability of your code is to use parenthesis, also called "round brackets," to specify the exact order of operations in your Java code (Nagler, 1995; Ambler, 1998a). If I have to know the order of operations for a language to understand your source code then something is seriously wrong. This is mostly an issue for logical comparisons where you AND and OR several other comparisons together. Note that if you use short, single command lines as suggested above then this really shouldn't crop up as an issue.

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2.5 Java Coding Tips

This section contains a collection of guidelines that I have found useful over the years to increase the quality of my source code.

2.5.1 Organize Your Code Sensibly

Compare the two code examples presented below. The one of the right is easier to understand because the statements involving **anObject** have been placed together. The code still does the same thing, it's just a little easier to read now (note that if **aCounter** had been passed as a parameter in **message3()** then this change couldn't have been made).

Code Examples:

anObject.message1(); **anObject.message2();** **aCounter = 1;** **anObject.message3();**	**anObject.message1();** **anObject.message2();** **anObject.message3();** **aCounter = 1;**

2.5.2 Place Constants on the Left Side of Comparisons

Consider the code examples below. Although they are both equivalent, at least on first inspection, the code on the left compiles and the code on the right does not. Why? Because the second if statement isn't doing a comparison, it's doing assignment – you can't assign a new value to a constant value such as 0. This can be a difficult bug to find in your code (at least without a sophisticated testing tool). By placing constants on the left side of comparisons you achieve the same effect and the compiler will catch it if you accidentally use assignment instead of comparison.

Code Examples:

if (something == 1) {…} **if (x = 0) { …}**	**if (1 == something) {…}** **if (0 = x) { …}**

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3. Standards for Fields (Attributes/Properties)

Throughout this white paper I will use the term *field* to refer to a attribute, which the Beans Development Kit (BDK) calls a property (DeSoto, 1997). A field is a piece of data that describes an object or class. Fields may be a base data type like a string or a float, or may be an object such as a customer or bank account.

3.1 Naming Fields

3.1.1 Use a Full English Descriptor for Field Names

You should use a full English descriptor to name your fields (Gosling, Joy, Steele, 1996; Ambler 1997) to make it obvious what the field represents. Fields that are collections, such as arrays or vectors, should be given names that are plural to indicate that they represent multiple values.

Examples:

firstName
zipCode
unitPrice
discountRate
orderItems
sqlDatabase

If the name of the field begins with an acronym, such as **sqlDatabase**, then the acronym (in this case 'sql') should be completely in lowercase. Do not use **sQLDatabase** for the name.

3.1.1.1 Alternative – Hungarian Notation

The "Hungarian Notation" (McConnell, 1993) is based on the principle that a field should be named using the following approach: xEeeeeeEeeeee where x indicates the component type and EeeeeEeeeee is the full English descriptor.

Examples:

sFirstName
iZipCode
lUnitPrice
lDiscountRate
cOrderItems

The main advantage is that this is an industry standard common for C++ code so many people already follow it. Furthermore, developers can quickly judge from the name of the variable its type and how it is used. The main disadvantages are that the prefix notation becomes cumbersome when you have a lot of the same type of attribute, you break from the full English descriptor naming convention, and your accessor method naming strategy is impacted (see Section 3.4.1).

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3.1.1.2 Alternative – Leading or Trailing Underscores

A common approach, coming from the C++ community, is to include either a leading or trailing underscore to the field name.

Examples:

_firstName
firstName_

The advantage of this approach is that you immediately know that you are dealing with a field, avoiding the name hiding issue with parameters and locals (although, once again, name hiding in this case isn't an issue if you use accessor methods). The main disadvantage is that this is not the standard set by Sun.

3.1.2 Naming Components (Widgets)

For names of components (interface widgets) you should use a full English descriptor postfixed by the widget type[3]. This makes it easy for you to identify the purpose of the component as well as its type, making it easier to find each component in a list (many visual programming environments provide lists of all components in an applet or application and it can be confusing when everything is named **button1**, **button2**, …).

Examples:

okButton
customerList
fileMenu
newFileMenuItem

3.1.2.1 Alternative for Naming Components – Hungarian Notation

Examples:

pbOk
lbCustomer
mFile
miNewFile

The advantages are the same as described above in Section 3.1.1.1. The main disadvantage is that the prefix notation becomes cumbersome when you have a lot of the same type of widget.

3.1.2.2 Alternative for Naming Components – Postfix-Hungarian Notation

Basically a combination of the other two alternatives, it results in names such as **okPb**, **customerLb**, **fileM**, and **newFileMi**. The main advantage is that the name of the component indicates the widget type and that widgets of the same type aren't grouped together in an alphabetical list. The main disadvantage is that you still aren't using a full English description, making the standard harder to remember because it deviates from the norm.

[3] This is my own standard and not one promoted by Sun.

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Tip – Set Component Name Standards

Whatever convention you choose, you'll want to create a list of "official" widget names. For example, when naming buttons do you use **Button** or **PushButton**, **b** or **pb**? Create a list and make it available to every Java developer in your organization.

3.1.3 Naming Constants

In Java, constants, values that do not change, are typically implemented as *static final* fields of classes. The recognized convention is to use full English words, all in uppercase, with underscores between the words (Gosling, Joy, Steele, 1996; Sandvik, 1996; NPS, 1996).

Examples:

MINIMUM_BALANCE
MAX_VALUE
DEFAULT_START_DATE

The main advantage of this convention is that it helps to distinguish constants from variables. We will see later in the document that you can greatly increase the flexibility and maintainability of your code by not defining constants, instead you should define getter member functions that return the value of constants.

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3.1.4 Naming Collections

A collection, such as an array or a vector, should be given a pluralized name representing the types of objects stored by the array. The name should be a full English descriptor with the first letter of all non-initial words capitalized.

Examples:

customers
orderItems
aliases

The main advantage of this convention is that it helps to distinguish fields that represent multiple values (collections) from those that represent single values (non-collections).

3.1.4.1 Alternative for Naming Collections – The 'Some' Approach

A non-standard approach, although an interesting one, is to prefix the name of a collection with 'some'.

Examples:

someCustomers
someOrderItems
someAliases

3.1.5 Do Not "Hide" Names

Name hiding refers to the practice of naming a local variable, argument, or field the same (or similar) as that of another one of greater scope. For example, if you have a field called **firstName** do not create a local variable or parameter called **firstName**, or anything close to it like **firstNames** or **fistName** (hey, maybe some people name their fists, personally I refer to mine as "left" and "right" <grin>). Try to avoid this as it makes your code difficult to understand and prone to bugs because other developers, or you, will misread your code while they are modifying it and make difficult to detect errors.

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3.2 Field Visibility

The Vision team (1996) suggests that fields not be declared *public* for reasons of encapsulation, but I would go further to state that all fields should be declared *private*. When fields are declared *protected* there is the possibility of member functions in subclasses to directly access them, effectively increasing the coupling within a class hierarchy. This makes your classes more difficult to maintain and to enhance, therefore it should be avoided. Fields should never be accessed directly, instead accessor member functions (see below) should be used.

Visibility	Description	Proper Usage
public	A public field can be accessed by any other member function in any other object or class.	Do not make fields public.
protected	A protected field can be accessed by any member function in the class in which it is declared or by any member functions defined in subclasses of that class.	Do not make fields protected.
private	A private field can only be accessed by member functions in the class in which it is declared, but not in the subclasses.	All fields should be private and be accessed by getter and setter member functions (accessors).

For fields that are not persistent (they will not be saved to permanent storage) you should mark them as either *static* or *transient* (DeSoto, 1997). This makes them conform to the conventions of the BDK.

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3.3 Documenting a Field

Every field should be documented well enough so that other developers can understand it. To be effective, you need to document:

1. **Its description.** You need to describe a field so that people know how to use it.

2. **Document all applicable invariants.** Invariants of a field are the conditions that are always true about it. For example, an invariant about the field **dayOfMonth** might be that its value is between 1 and 31 (obviously you could get far more complex with this invariant, restricting the value of the field based on the month and the year). By documenting the restrictions on the value of a field you help to define important business rules, making it easier to understand how your code works (or at least should work).

3. **Examples.** For fields that have complex business rules associated with them you should provide several example values so as to make them easier to understand. An example is often like a picture: it is worth a thousand words.

4. **Concurrency issues.** Concurrency is a new and complex concept for many developers, actually, at best it is an old and complex topic for experienced concurrent programmers. The end result is that if you use the concurrent programming features of Java then you need to document it thoroughly.

5. **Visibility decisions.** If you've declared a field to be anything but private then you should document why you have done so. Field visibility is discussed in section 3.2 above, and the use of accessor member functions to support encapsulation is covered in section 3.4 below. The bottom line is that you better have a really good reason for not declaring a variable as private.

3.4 The Use of Accessor Member Functions

In addition to naming conventions, the maintainability of fields is achieved by the appropriate use of *accessor member functions*, member functions that provide the functionality to either update a field or to access its value. Accessor member functions come in two flavors: *setters* (also called *mutators*) and *getters*. A setter modifies the value of a variable, whereas a getter obtains it for you.

Although accessor member functions used to add overhead to your code, Java compilers are now optimized for their use, this is no longer true. Accessors help to hide the implementation details of your class. By having at most two control points from which a variable is accessed, one setter and one getter, you are able to increase the maintainability of your classes by minimizing the points at which changes need to be made. Optimization of Java code is discussed in section 7.3.

One of the most important standards that your organization can enforce is the use of accessors. Some developers do not want to use accessor member functions because they do not want to type the few extra keystrokes required (for example, for a getter you need to type in 'get' and '()' above and beyond the name of the field). The bottom line is that the increased maintainability and extensibility from using accessors more than justifies their use.

Tip – Accessors Are The Only Place To Access Fields

A key concept with the appropriate use of accessor member functions is that the ONLY member functions that are allowed to directly work with a field are the accessor member functions themselves. Yes, it is possible for directly access a private field within the member functions of the class in which the field is defined but you do not want to do so because you would increase the coupling within your class.

3.4.1 Naming Accessors

Getter member functions should be given the name 'get' + field name, unless the field represents a boolean (true or false) and then the getter is given the name 'is' + field name. Setter member functions should be given the name 'set' + field name, regardless of the field type (Gosling, Joy & Steele, 1996; DeSoto, 1997). Note that the field name is always in mixed case with the first letter of all words capitalized. This naming convention is used consistently within the JDK and is what is required for beans development.

Examples:

Field	Type	Getter name	Setter name
firstName	string	**getFirstName()**	**setFirstName()**
address	**SurfaceAddress** object	**getAddress()**	**setAddress()**
persistent	boolean	**isPersistent()**	**setPersistent()**
customerNumber	int	**getCustomerNumber()**	**setCustomerNumber()**
orderItems	Array of **OrderItem** objects	**getOrderItems()**	**setOrderItems()**

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3.4.2 Advanced Techniques for Accessors

Accessors can be used for more than just getting and setting the values of instance fields. In this section we will discuss how to increase the flexibility of your code by using accessors to:

- Initialize the values of fields
- Access constant values
- Access collections
- Access several fields simultaneously

3.4.2.1 Lazy Initialization

Variables need to be initialized before they are accessed. There are two lines of thought to initialization: Initialize all variables at the time the object is created (the traditional approach) or initialize at the time of first use. The first approach uses special member functions that are invoked when the object is first created, called constructors. Although this works, it often proves to be error prone. When adding a new variable you can easily forget to update the constructor(s). An alternative approach is called *lazy initialization* where fields are initialized by their getter member functions, as shown below[4]. Notice the member function checks to see if the branch number is zero, if it is, then it sets it to the appropriate default value.

```
/**
    Answers the branch number, which is the leftmost
    four digits of the full account number.
    Account numbers are in the format BBBBAAAAAA.
  */
  protected int getBranchNumber()
  {
    if( branchNumber == 0)
    {
      // The default branch number is 1000, which
      // is the main branch in downtown Bedrock.
      setBranchNumber(1000);
    }
    return branchNumber;
  }
```

It is quite common to use lazy initialization for fields that are actually other objects stored in the database. For example, when you create a new inventory item you do not need to fetch whatever inventory item type from the database that you've set as a default. Instead, use lazy initialization to set this value the first time it is accessed so that you only have to read the inventory item type object from the database when and if you need it. This approach is advantageous for objects that have fields that aren't regularly accessed – Why incur the overhead of retrieving something from persistent storage if you aren't going to use it?

Whenever lazy initialization is used in a getter member function you should document why the default value is what it is, as we saw in the example above. When you do this you take the mystery out of how fields are used in your code, improving both its maintainability and extensibility.

[4] Note how a setter member function is used within the getter member function.

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3.4.2.2 Getters for Constants

The common Java wisdom, perhaps wisdom is the wrong term, is to implement constant values as static final fields. This approach makes sense for "constants" that are guaranteed to be stable. For example the class **Boolean** implements two *static final* fields called **TRUE** and **FALSE** which represents the two instances of that class. It would also make sense for a **DAYS_IN_A_WEEK** constant whose value probably is never going to change[5].

However, many so-called business "constants" change over time because the business rule changes. Consider the following example: The Archon Bank of Cardassia (ABC) has always insisted that an account has a minimum balance of $500 if it is to earn interest. To implement this, we could add a static field named **MINIMUM_BALANCE** to the class Account that would be used in the member functions that calculate interest. Although this would work, it isn't flexible. What happens if the business rules change and different kinds of accounts have different minimum balances, perhaps $500 for savings accounts but only $200 for checking accounts? What would happen if the business rule were to change to a $500 minimum balance in the first year, $400 in the second, $300 in the third, and so on? Perhaps the rule will be changed to $500 in the summer but only $250 in the winter?[6] Perhaps a combination of all of these rules will need to be implemented in the future.

The point to be made is that implementing constants as fields isn't flexible, a much better solution is to implement constants as getter member functions. In our example above, a static (class) member function called **getMinimumBalance()** is far more flexible than a static field called **MINIMUM_BALANCE** because we can implement the various business rules in this member function and subclass it appropriately for various kinds of accounts.

```
/**
        Get the value of the account number.   Account numbers are in the following
        format: BBBBAAAAAA,  where BBBB is the branch number and
        AAAAAA is the branch account number.
  */
  public long getAccountNumber()
  {
     return ( ( getBranchNumber() * 100000 ) + getBranchAccountNumber() );
  }


/**
        Set the account number.  Account numbers are in the following
        format: BBBBAAAAAA where BBBB is the branch number and
        AAAAAA is the branch account number.
  */
  public void setAccountNumber(int newNumber)
  {
     setBranchAccountNumber( newNumber % 1000000 );
     setBranchNumber( newNumber / 1000000 );
  }
```

[5] I'm assuming that all cultures have a 7-day week, something that I do not know for sure. I have been involved with the development of enough international applications to know that I really need to verify this assumption. You really learn a lot on projects involving localization issues, I highly suggest getting on one.
[6] Hey, I'm Canadian. This could happen.

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Another advantage of constant getters is that they help to increase consistency of your code. Consider the code shown above – it doesn't work properly. An account number is the concatenation of the branch number and the branch account number. Testing our code, we find that the setter member function, **setAccountNumber()** doesn't update branch account numbers properly. That is because it used 100,000 instead of 1,000,000 to extract the field **branchAccountNumber**. Had we used a single source for this value, the constant getter **getAccountNumberDivisor()** as we see in below, our code would have been more consistent and would have worked.

```
/**
        Returns the divisor needed to separate the branch account number from the
        branch number within the full account number.
        Full account numbers are in the format BBBBAAAAAA.
 */
 public long  getAccountNumberDivisor()
 {
    return ( (long) 1000000);
 }

/**
        Get the value of the account number.   Account numbers are in the following
        format: BBBBAAAAAA,  where BBBB is the branch number and
        AAAAAA is the branch account number.
 */
 public long getAccountNumber()
 {
        return ( ( getBranchNumber() * getAccountNumberDivisor() ) +
                                                getBranchAccountNumber() );
 }


/**
        Set the account number.  Account numbers are in the following
        format: BBBBAAAAAA where BBBB is the branch number and
        AAAAAA is the branch account number.
 */
 public void setAccountNumber(int newNumber)
 {
    setBranchAccountNumber( newNumber % getAccountNumberDivisor() );
    setBranchNumber( newNumber / getAccountNumberDivisor() );
 }
```

By using accessors for constants we decrease the chance of bugs and at the same time increase the maintainability of our system. When the layout of an account number changes, and we know that it eventually will (users are like that), chances are that our code will be easier to change because we've both hidden and centralized the information needed to build/break up account numbers.

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3.4.2.3 Accessors for Collections

The main purpose of accessors is to encapsulate the access to fields so as to reduce the coupling within your code. Collections, such as arrays and vectors, being more complex than single value fields naturally need to have more than just the standard getter and setter member function implemented for them. In particular, because you can add and remove to and from collections, accessor member functions need to be included to do so. The approach that I use is to add the following accessor member functions where appropriate for a field that is a collection:

Member Function type	Naming convention	Example
Getter for the collection	**getCollection()**[7]	**getOrderItems()**
Setter for the collection	**setCollection()**	**setOrderItems()**
Insert an object into the collection	**insertObject()**	**insertOrderItem()**
Delete an object from the collection	**deleteObject()**	**deleteOrderItem()**
Create and add a new object into the collection	**newObject()**	**newOrderItem()**

The advantage of this approach is that the collection is fully encapsulated, allowing you to later replace it with another structure, perhaps a linked list or a B-tree.

3.4.2.4 Accessing Several Fields Simultaneously

One of the strengths of accessor member functions is that they enable you to enforce business rules effectively. Consider for example a class hierarchy of shapes. Each subclass of **Shape** knows its position via the use of two fields – **xPosition** and **yPosition** – and can be moved on the screen on a two-dimensional plane via invoking the member function **move(Float xMovement, Float yMovement)**. For our purposes it doesn't make sense to move a shape along one axis at a time, instead we will move along both the x and the y axis simultaneously (it is acceptable to pass a value of 0.0 as for either parameter of the **move()** member function). The implication is that the **move()** member function should be public, but the member functions **setXPosition()** and **setYPosition()** should both be private, being invoked by the **move()** member function appropriately.

An alternative implementation would be to introduce a setter member function that updates both fields at once, as shown below. The member functions **setXPosition()** and **setYPosition()** would still be private so that they may not be invoked directly by external classes or subclasses (you would want to add some documentation, shown below, indicating that they should not be directly invoked).

[7] Remember, the naming convention for collections is to use a pluralized version of the type of information that it contains. Therefore a collection of order item objects would be called **orderItems**.

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```
/**
        Set the position of the shape
*/
protected void setPosition(Float x, Float y)
{
        setXPosition(x);
        setYPosition(y);
}

/**
        Set the x position – Important: Invoke setPosition(), not this member function.
*/
private void setXPosition(Float x)
{
        xPosition = x;
}

/**
        Set the y position of the shape
        Important: Invoke setPosition(), not this member function.
*/
private void setYPosition(Float y)
{
        yPosition = y;
}
```

*Important note to all of the nitpickers out there: Yes, I could have implemented this with a single instance of **Point**, but I did it this way for an easy example.*

3.4.3 Visibility of Accessors

Always strive to make them protected, so that only subclasses can access the fields. Only when an 'outside class' needs to access a field should you make the corresponding getter or setter public. Note that it is common that the getter member function be public and the setter protected.

Sometimes you need to make setters private to ensure certain invariants hold. For example, an **Order** class may have a field representing a collection of **OrderItem** instances, and a second field called **orderTotal** which is the total of the entire order. The **orderTotal** is a convenience field that is the sum of all sub-totals of the ordered items. The only member functions that should update the value of **orderTotal** are those that manipulate the collection of order items. Assuming that those member functions are all implemented in **Order**, you should make **setOrderTotal()** private, even though **getOrderTotal()** is more than likely public.

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3.4.4 Why Use Accessors?

I think that Kanerva (1997) says it best: "Good program design seeks to isolate parts of a program from unnecessary, unintended, or otherwise unwanted outside influences. Access modifiers (accessors) provide an explicit and checkable means for the language to control such contacts." Accessor member functions improve the maintainability of your classes in the following ways:

1. **Updating fields**. You have single points of update for each field, making it easier to modify and to test. In other words your fields are encapsulated.

2. **Obtaining the values of fields**. You have complete control over how fields are accessed and by whom.

3. **Obtaining the values of constants and the names of classes**. By encapsulating the value of constants and of class names in getter member functions when those values/names change you only need to update the value in the getter and not every line of code where the constant/name is used.

4. **Initializing fields**. The use of lazy initialization ensures that fields are always initialized and that they are initialized only if they are needed.

5. **Reduction of the coupling between a subclass and its superclass(es)**. When subclasses access inherited fields only through their corresponding accessor member functions, it makes it possible to change the implementation of fields in the superclass without affecting any of its subclasses, effectively reducing coupling between them. Accessors reduce the risk of the "fragile base class problem" where changes in a superclass ripple throughout its subclasses.

6. **Encapsulating changes to fields**. If the business rules pertaining to one or more fields change you can potentially modify your accessors to provide the same ability as before the change, making it easier for you to respond to the new business rules.

7. **Simplification of concurrency issues.** Lea (1997) points out that setter member functions provide a single place to include a *notifyAll* if you have waits based on the value of that field. This makes moving to a concurrent solution much easier.

8. **Name hiding becomes less of an issue.** Although you should avoid name hiding, giving local variables the same names as fields, the use of accessors to always access fields means that you can give local variables any name you want – You do not have to worry about hiding field names because you never access them directly anyway.

3.4.5 Why Shouldn't You Use Accessors?

The only time that you might want to not use accessors is when execution time is of the utmost importance, however, it is a very rare case indeed that the increased coupling within your application justifies this action. Lea (1996) makes a case for minimizing the use of accessors on the grounds that it is often the case that the values of fields in combination must be consistent, and that it isn't wise to provide access to fields singly. He's right, so do not! I think that Lea has missed the point that you do not need to make all accessor member functions public. When you are in the situation that the values of some fields depend upon one another then you should introduce member functions that do the "right thing" and make the appropriate accessor member functions either protected or private as needed. You do not have to make all of your accessors public.

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3.5 Always Initialize Static Fields

Doug Lea (1996) validly points out that you must ensure that static fields, also known as class fields, be given valid values because you can't assume that instances of a class will be created before a static field is accessed. Lea suggests the use of static initializers (Grand, 1997), static blocks of code which are automatically run when a class is loaded. Note that this is a problem only if you choose not to use accessor member functions for static fields – With accessor member functions you can always use lazy initialization to guarantee that the value of a field is set. The use of accessor member functions to encapsulate fields gives you complete control over how they are used, while reducing coupling within your code. A win-win situation.

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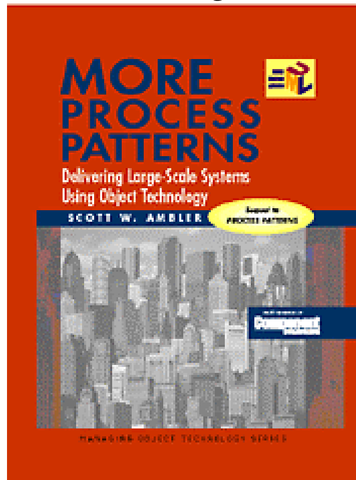

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4. Standards for Local Variables

A local variable is an object or data item that is defined within the scope of a block, often a member function. The scope of a local variable is the block in which it is defined. The important coding standards for local variables focus on:

- Naming conventions
- Documentation conventions
- Declarations

4.1 Naming Local Variables

In general, local variables are named following the same conventions as used for fields, in other words use full English descriptors with the first letter of any non-initial word in uppercase.

For the sake of convenience, however, this naming convention is relaxed for several specific types of local variable:

- Streams
- Loop counters
- Exceptions

4.1.1 Naming Streams

When there is a single input and/or output stream being opened, used, and then closed within a member function the common convention is to use **in** and **out** for the names of these streams, respectively (Gosling, Joy, Steele, 1996). For a stream used for both input and output, the implication is to use the name **inOut.**

A common alternative to this naming convention is to use the names **inputStream**, **outputStream**, and **ioStream** instead of **in**, **out**, and **inOut** respectively. To tell you the truth I like this alternative better, but the fact remains that the names **in** and **out** are what Sun suggests, so that's what you should probably stick with.

4.1.2 Naming Loop Counters

Because loop counters are a very common use for local variables, and because it was acceptable in C/C++, in Java programming the use of **i**, **j**, or **k**, is acceptable for loop counters (Gosling, Joy, Steele, 1996; Sandvik, 1996). If you use these names for loop counters, use them consistently.

A common alternative is to use names like **loopCounter** or simply counter, but the problem with this approach is that you often find names like **counter1** and **counter2** in member functions that require more than one counter. The bottom line is that **i**, **j**, **k** work as counters, they're quick to type in, and they're generally accepted.

A major disadvantage of using single letter names for counters, or for anything, is that when you try to search for its use within a code file you will obtain many false hits – consider the ease of searching for **loopCounter** over the letter **i**.

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4.1.3 Naming Exception Objects

Because exception handling is also very common in Java coding the use of the letter **e** for a generic exception is considered acceptable (Gosling, Joy, Steele, 1996; Sandvik, 1996).

4.1.4 Bad Ideas for Naming Local Variables

Unfortunately a few "common" short names have been approved for local variables, but frankly I think they're inappropriate. In the chart below I have summarized the naming conventions put forth by Sun for other types of common objects/variables used in Java (Gosling, Joy, Steele, 1996). I'm sorry, but it is my opinion that these conventions have crossed the hacking line and actually reduce the readability of your source code. Use these conventions if you want to, but I do not recommend them.

Variable Type	Suggested Naming Convention
offset	**off**
length	**len**
byte	**b**
char	**c**
double	**d**
float	**f**
long	**l**
Object	**o**
String	**s**
Arbitrary value	**v**

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4.2 Declaring and Documenting Local Variables

There are several conventions regarding the declaration and documentation of local variable in Java. These conventions are:

1. **Declare one local variable per line of code.** This is consistent with one statement per line of code and makes it possible to document each variable with an endline comment (Vision, 2000).

2. **Document local variables with an endline comment.** Endline commenting is a style in which a single line comment, denoted by //, immediately follows a command on the same line of code (this is called an endline comment). You should document what a local variable is used for and where appropriate why it is used, making your code easier to understand.

3. **Declare local variables immediately before their use.** By declaring local variables where they are first needed other programmers do not need to scroll to the top of the member function to find out what a local variable is used for. Furthermore, your code may be more efficient because if that code is never reached the variable will not need to be allocated (Vision, 1996). The main disadvantage of this approach is that your declarations are dispersed throughout each of your member functions, making it difficult to find all declarations in large member functions.

4. **Use local variables for one thing only.** Whenever you use a local variable for more than one reason you effectively decrease its cohesion, making it difficult to understand. You also increase the chances of introducing bugs into your code from the unexpected side effects of previous values of a local variable from earlier in the code. Yes, reusing local variables is more efficient because less memory needs to be allocated, but reusing local variables decreases the maintainability of your code and makes it more fragile. This usually isn't worth the small savings from not having to allocate more memory.

4.2.1 General Comments About Declaration

Local variables that are declared between lines of code, for example within the scope of an if statement, can be difficult to find by people not familiar with your code.

One alternative to declaring local variables immediately before their first use is to instead declare them at the top of the code. Because your member functions should be short anyway, see Section 2.4.6, it shouldn't be all that bad having to go to the top of your code to determine what the local variable is all about.

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5. Standards for Parameters (Arguments) To Member Functions

The standards that are important for parameters/arguments to member functions focus on how they are named and how they are documented. Throughout this white paper I will use the term *parameter* to refer to a member function argument.

5.1 Naming Parameters

Parameters should be named following the exact same conventions as for local variables. As with local variables, name hiding is an issue (if you aren't using accessors).

Examples:

customer
inventoryItem
photonTorpedo
in
e

5.1.1 Alternative – Prefix Parameter Names with 'a' or 'an'

A viable alternative, taken from Smalltalk, is to use the naming conventions for local variables, with the addition of "a" or "an" on the front of the name. The addition of "a" or "an" helps to make the parameter stand out from local variables and fields, and avoids the name-hiding problem. This is my preferred approach.

Examples:

aCustomer
anInventoryItem
aPhotonTorpedo
anInputStream
anException

5.1.2 Alternative – Name Parameters Based on Their Type

Another alternative to naming variables, which I do not recommend at all, is to give them a name based on their type. This is a bad idea for several reasons: First, the type is already indicated in the definition of the member function. Second, a parameter name like **aString** tells you much less information than a name like **accountNumber** or **firstName**.

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5.1.3 Alternative – Name Parameters The Same as Their Corresponding Fields (if any)

A third alternative (Gosling, The Java Programming Language) is to name parameters that align to an existing field with the same name as the existing field. For example, if **Account** has an attribute called **balance** and you needed to pass a parameter representing a new value for it the parameter would be called **balance**. The field would be referred to as **this.balance** in the code and the parameter would be referred to as **balance** (you could also invoke the appropriate accessor method). Although this is a viable approach my experience is that you're playing with fire as it's too easy to forget the "this." I would avoid this approach if possible as you'll likely have name hiding issues to deal with.

5.2 Documenting Parameters

Parameters to a member function are documented in the header documentation for the member function using the *javadoc @param* tag. You should describe:

1. **What it should be used for.** You need to document what a parameter is used for so that other developers understand the full context of how the parameter is used.

2. **Any restrictions or preconditions.** If the full range of values for a parameter is not acceptable to a member function, then the invoker of that member function needs to know. Perhaps a member function only accepts positive numbers, or strings of less than five characters.

3. **Examples.** If it is not completely obvious what a parameter should be, then you should provide one or more examples in the documentation.

Tip – Use Interfaces for Parameter Types

Instead of specifying a class, such as **Object**, for the type of a parameter, if appropriate specify an interface, such as **Runnable**, if appropriate. The advantage is that this approach, depending on the situation, can be more specific (Runnable is more specific than Object), or may potentially be a better way to support polymorphism (instead of insisting on a parameter being an instance of a class in a specific class hierarchy, you specify that it supports a specific interface implying that it only needs to be polymorphically compliant to what you need)

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6. Standards for Classes, Interfaces, Packages, and Compilation Units

This chapter concentrates on standards and guidelines for classes, interfaces, packages, and compilation units. A class is a template from which objects are instantiated (created). Classes contain the declaration of fields and member functions. Interfaces are the definition of a common signature, including both member functions and fields, which a class that implements an interface must support. A package is a collection of related classes. Finally, a compilation unit is a source code file in which classes and interfaces are declared. Because Java allows compilation units to be stored in a database, an individual compilation unit may not directly relate to a physical source code file.

6.1 Standards for Classes

The standards that are important for classes are based on:

- Visibility
- Naming conventions
- Documentation conventions
- Declaration conventions
- The public and protected interface

6.1.1 Class Visibility

Classes may have one of two visibilities: public or package (default). Public visibility is indicated with the keyword public and package visibility is not indicated (there is no keyword). Public classes are visible to all other classes whereas classes with package visibility are visible only to classes within the same package.

1. **Use package visibility for classes internal to a component**. With package visibility you hide classes within the package, effectively encapsulating them within your component.

2. **Use public visibility for the facades of components**. Components are encapsulated by façade classes, classes that implement the interface of the component and that route messages to classes internal to the component.

6.1.2 Naming Classes

The standard Java convention is to use a full English descriptor starting with the first letter capitalized using mixed case for the rest of the name (Gosling, Joy, Steele, 1996; Sandvik, 1996; Ambler, 1998a).

Examples:

Customer
Employee
Order
OrderItem
FileStream
String

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6.1.3 Documenting a Class

The following information should appear in the documentation comments immediately preceding the definition of a class:

1. **The purpose of the class.** Developers need to know the general purpose of a class so they can determine whether or not it meets their needs. I also make it a habit to document any good things to know about a class, for example is it part of a pattern or are there any interesting limitations to using it (Ambler, 1998a).

2. **Known bugs[8].** If there are any outstanding problems with a class they should be documented so that other developers understand the weaknesses/difficulties with the class. Furthermore, the reason for not fixing the bug should also be documented. Note that if a bug is specific to a single member function then it should be directly associated with the member function instead.

3. **The development/maintenance history of the class.** It is common practice to include a history table listing dates, authors, and summaries of changes made to a class (Lea, 1996). The purpose of this is to provide maintenance programmers insight into the modifications made to a class in the past, as well as to document who has done what to a class. As with member functions, this information is better contained in a configuration management system, not the source file itself.

4. **Document applicable invariants.** An invariant is a set of assertions about an instance or class that must be true at all "stable" times, where a stable time is defined as the period before a member function is invoked on the object/class and immediately after a member function is invoked (Meyer, 1988). By documenting the invariants of a class you provide valuable insight to other developers as to how a class can be used.

5. **The concurrency strategy**. Any class that implements the interface **Runnable** should have its concurrency strategy fully described. Concurrent programming is a complex topic that is new for many programmers, therefore you need to invest the extra time to ensure that people can understand your work. It is important to document your concurrency strategy and why you chose that strategy over others. Common concurrency strategies (Lea, 1997) include the following: Synchronized objects, balking objects, guarded objects, versioned objects, concurrency policy controllers, and acceptors.

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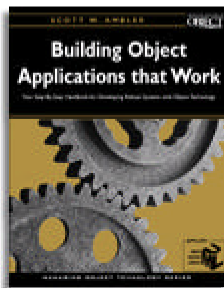

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[8] Yes, it is better to fix bugs. However, sometimes you do not have the time to do so or it isn't important to your work at the moment. For example, you might know that a member function will not work properly when passed a negative number, but that it does work properly for positive numbers. Your application only passes it positive numbers, so you can live with the bug but decide to be polite and document that the problem exists.

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6.1.4 Class Declarations

6.1.4.1 Apply The "final" Keyword Sensibly

Use the keyword **final** to indicate that your class can not be inherited from. This is a design decision on the part of the original developer, one that should not be taken lightly.

6.1.4.2 Ordering Member Functions and Fields

One way to make your classes easier to understand is to declare them in a consistent manner. The common approach in Java is to declare a class in the order of most visible to least visible (NPS, 1996), enabling you to discover the most important features, the public ones, first. Laffra (1997) points out that constructors and **finalize()** should be listed first, presumably because these are the first member functions that another developer will look at first to understand how to use the class. Furthermore, because we have a standard to declare all fields as private, the declaration order really boils down to:

constructors
finalize()
public member functions
protected member functions
private member functions
private fields

Within each grouping of member functions it is common to list them in alphabetical order. Many developers choose to list the static member functions within each grouping first, followed by instance member functions, and then within each of these two sub-groupings list the member functions alphabetically. Both of these approaches are valid, you just need to choose one and stick to it.

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6.1.5 Minimize the Public and Protected Interface

One of the fundamentals of object-oriented design is to minimize the public interface of a class. There are several reasons for this:

1. **Learnability.** To learn how to use a class you should only have to understand its public interface. The smaller the public interface, the easier a class is to learn.

2. **Reduced coupling.** Whenever the instance of one class sends a message to an instance of another class, or directly to the class itself, the two classes become coupled. Minimizing the public interface implies that you are minimizing the opportunities for coupling.

3. **Greater flexibility.** This is directly related to coupling. Whenever you want to change the way that a member function in your public interface is implemented, perhaps you want to modify what the member function returns, then you potentially have to modify any code that invokes the member function. The smaller the public interface the greater the encapsulation and therefore the greater your flexibility.

It is clear that it is worth your while to minimize the public interface, but often what isn't so clear is that you also want to minimize the protected interface as well. The basic idea is that from the point of view of a subclass, the protected interfaces of all of its superclasses are effectively public – Any member function in the protected interface can be invoked by a subclass. Therefore, you want to minimize the protected interface of a class for the same reasons that you want to minimize the public interface.

Tip – Define The Public Interface First

Most experienced developers define the public interface of a class before they begin coding it. First, if you do not know what services/behaviors a class will perform, then you still have some design work to do. Second, it enables them to stub out the class quickly so that other developers who rely on it can at least work with the stub until the "real" class has been developed. Third, this approach provides you with an initial framework around which to build your class.

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6.2 Standards for Interfaces

The standards that are important for interfaces are based on:
- Naming conventions
- Documentation conventions

6.2.1 Naming Interfaces

The Java convention is to name interfaces using mixed case with the first letter of each word capitalized. The preferred Java convention for the name of an interface is to use a descriptive adjective, such as **Runnable** or **Cloneable**, although descriptive nouns, such as **Singleton** or **DataInput**, are also common (Gosling, Joy, Steele, 1996).

Alternatives:

1. **Prefix the letter 'I' to the interface name.** Coad and Mayfield (1997) suggest appending the letter 'I' to the front of an interface names, resulting in names like **ISingleton** or **IRunnable**. This approach helps to distinguish interface names from class and package names. I like this potential naming convention for the simple fact that it makes your class diagrams, sometimes referred to as object models, easier to read. The main disadvantage is that the existing interfaces, such as **Runnable**, aren't named using this approach, and I do not see them ever changing. Therefore I chose the defacto standard described above. This interface naming convention is also popular for Microsoft's COM/DCOM architecture.

2. **Postfix 'Ifc' onto the interface name.** Lea (1996) suggests appending 'Ifc' to the end of an interface name, resulting in names like **SingletonIfc** or **RunnableIfc**, whenever the name of an interface is similar to that of a class (Lea, 1996). I like the general idea, although I would be tempted to prefix the name with the full word 'Interface.' This suggestion suffers from the same problem as the one above.

6.2.2 Documenting Interfaces

The following information should appear in the documentation comments immediately preceding the definition of an interface:

1. **The purpose.** Before other developers will use an interface, they need to understand the concept that it encapsulates. In other words, they need to know its purpose. A really good test of whether or not you need to define an interface is whether or not you can easily describe its purpose. If you have difficulties describing it, then chances are pretty good you do not need the interface to begin with. Because the concept of interfaces is new to Java, people are not yet experienced in their appropriate use and they are likely to overuse them because they are new. Just like the concept of inheritance, and in particular multiple inheritance, was greatly abused by developers new to object-orientation, I suspect that interfaces will also be greatly abused at first by programmers new to Java.

2. **How it should and shouldn't be used.** Developers need to know both how an interface is to be used, as well as how it shouldn't be used (Coad & Mayfield, 1997).

Because the signature for member functions is defined in an interface, for each member function signature you should follow the member function documentation conventions discussed in chapter 2.

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6.3 Standards for Packages

The standards that are important for packages are based on:

- Naming conventions
- Documentation conventions

6.3.1 Naming Packages

There are several rules associated with the naming of packages. In order, these rules are:

1. **Identifiers are separated by periods.** To make package names more readable, Sun suggests that the identifiers in package names be separated by periods. For example, the package name **java.awt** is comprised of two identifiers, **java** and **awt**.

2. **The standard java distribution packages from Sun begin with the identifier 'java' or 'javax'.** Sun has reserved this right so that the standard java packages are named in a consistent manner regardless of the vendor of your Java development environment.

3. **Local package names begin with an identifier that is not all upper case.** Local packages are ones that are used internally within your organization and that will not be distributed to other organizations. Examples of these package names include **persistence.mapping.relational** and **interface.screen**.

4. **Global package names begin with the reversed Internet domain name for your organization.** A package that is to be distributed to multiple organizations should include the name of the originating organization's domain name, with the top-level domain type in lower case. For example, to distribute the previous packages, I would name them **com.ambysoft.www.persistence.mapping.relational** and **com.ambysoft.www.interface.screens**. The prefix (.com) should be lower case and should be one of the standard Internet top-level domain names (currently com, edu, gov, mil, net, org).

5. **Package names should be singular**. The common convention is to use singular names for package names, such as **interface.screen**, and not a plural, such as **interface.screens**.

6.3.2 Documenting a Package

You should maintain one or more external documents that describe the purpose of the packages developed by your organization. For each package you should document:

1. **The rationale for the package.** Other developers need to know what a package is all about so that they can determine whether or not they want to use it, and if it is a shared package whether or not they want to enhance or extend it.

2. **The classes in the package.** Include a list of the classes and interfaces in the package with a brief, one-line description of each so that other developers know what the package contains.

Lea (1996) suggests creating an HTML file called *index.html* for each package, putting the file into the appropriate directory for the package. A better name would be the fully qualified name of the package, postfixed with *.html*, so that you do not have to worry about accidentally overwriting one package documentation file with another. I like Lea's idea, in general, but my experience has shown that similarly named files get overwritten often enough to modify his approach slightly.

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6.4 Standards for Compilation Units

The standards and guidelines for compilation units are based on:
- Naming conventions
- Documentation conventions

6.4.1 Naming a Compilation Unit

A compilation unit, in this case a source code file, should be given the name of the primary class or interface that is declared within it. Use the same name for the package/class for the file name, using the same case. The extension **.java** should be postfixed to the file name.

Examples:

Customer.java
Singleton.java
SavingsAccount.java

6.4.2 Documenting a Compilation Unit

Although you should strive to have only one class or interface declaration per file, it sometimes makes sense to define several classes (or interfaces) in the same file. My general rule of thumb is that if the sole purpose of class B is to encapsulate functionality that is needed only by class A then it makes sense that class B appear in the same source code file as class A[9]. As a result, I have separated the following documentation conventions that apply to a source code file, and not specifically to a class:

1. **For files with several classes, list each class.** If a file contains more than one class you should provide a list of the classes and a brief description for each (Lea, 1996).

2. **[OPTIONAL] The file name and/or identifying information.** The name of the file should be included at the top of it (Lea, 1996). The advantage is that if the code is printed you know what the source file for the code is. The disadvantage is that if you change the source file name you also need to update your documentation, therefore if you have a sophisticated source control system (and if you don't then get one) you might want to not include the source file name.

3. **Copyright information.** If applicable you should indicate any copyright information for the file (Lea, 1996). It is common to indicate the year of the copyright and the name of the individual/organization that holds the copyright. Note that the code author may not be the holder of the copyright.

[9] The concept of an "inner" class was introduced in JDK 1.1, which would be one option for implementing class B.

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7. Miscellaneous Standards/Issues

In this chapter I want to share with you several standards/guidelines that are important, but that are general enough that they need their own chapter.

7.1 Reuse

Any Java class library or package that you purchase/reuse from an external source should be certified as 100% pure Java (Sun, 1997). By enforcing this standard you are guaranteed that what you are reusing will work on all platforms that you choose to deploy it on. You can obtain Java classes, packages, or applets from a variety of sources, either a third-party development company that specializes in Java libraries or another division or project team within your organization.

Scott's Soapbox – 100% Pure is 100% Dead On

In my opinion the 100% Pure effort from Sun is exactly what Java needs. In my second book, *Building Object Applications That Work* (Ambler, 1998a), I had a few harsh words about the portability of Java. There are two portability issues with Java: Source code portability and bytecode portability. At the time of this writing, May 1997, I think that developers porting from JDK 1.0 to JDK 1.1 now have a better appreciation for what I was talking about. In many ways the 100% Pure effort is Sun's recognition that portability doesn't come free just because you use Java, you actually have to work at it to ensure that your code is portable. With multiple vendors of Java, several of whom would like to mold Java in their own image, without something like the 100% Pure effort Java code will become just as portable as C code – Not very.

Sun's message to the other Java vendors and to Java developers is clear: Proprietary Java solutions will not be tolerated.

7.2 Use Wild Cards When Importing Classes

The import statement allows the use of wildcards when indicating the names of classes. For example, the statement

import java.awt.*;

brings in all of the classes in the package **java.awt** at once. Actually, that's not completely true. What really happens is that every class that you use from the **java.awt** package will be brought into your code when it is compiled, classes that you do not use will not be.

7.2.1 Alternative – Explicitly Specify Each Imported Class

Another approach is to fully qualify the name of the classes that your code uses (Laffra, 1997; Vision, 1996), as shown in the example below:

```
import java.awt.Color;
import java.awt.Button;
import java.awt.Container;
```

The problem with this approach is that it increases your maintenance burden – you need to keep your import list accurate whenever you add a new class (the compiler will force this on you) and whenever you stop using a class (you need to do this yourself).

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7.3 Optimizing Java Code

I have left my discussion of Java code optimization toward the end of this white paper for a reason: optimizing your code is one of the last things that programmers should be thinking about, not one of the first. My experience is that you want to leave optimization to the end because you want to optimize only the code that needs it – very often a small percentage of your code results in the vast majority of the processing time, and this is the code that you should be optimizing. A classic mistake made by inexperienced programmers is to try to optimize all of their code, even code that already runs fast enough. Personally, I prefer to optimize the code that needs it and then move on to more interesting things than trying to squeeze out every single CPU cycle.

Do not waste your time optimizing code that nobody cares about.

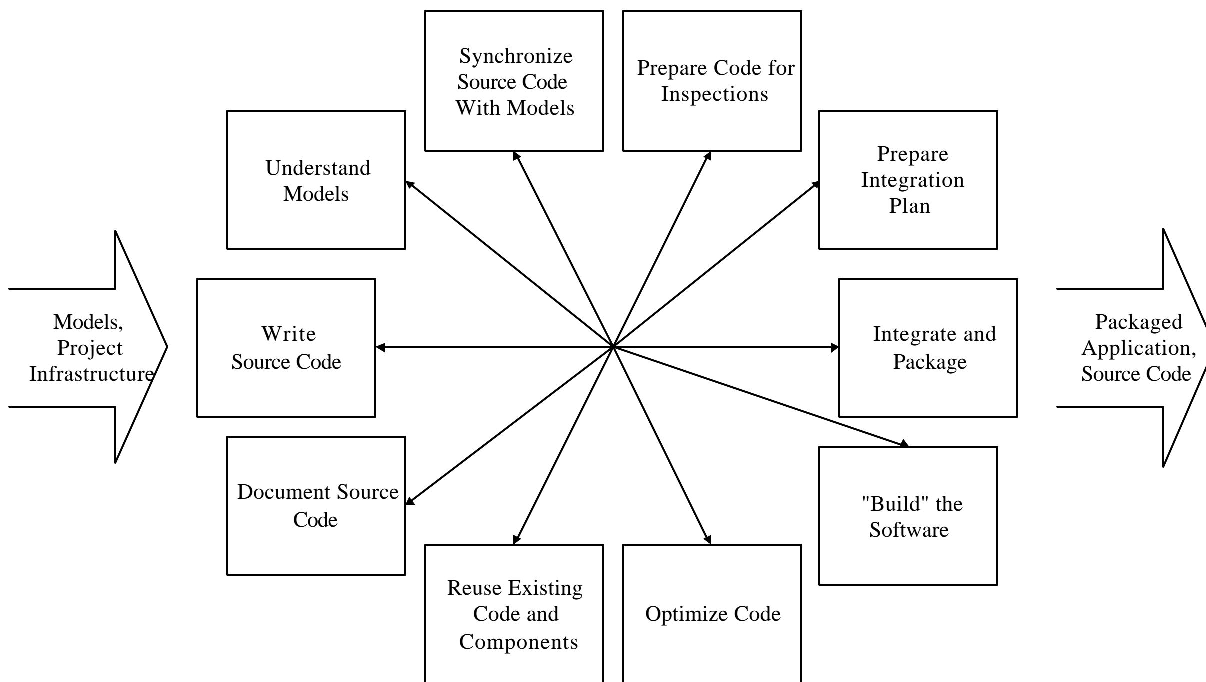

Figure 1. The Program process pattern.

Figure 1 presents the Program stage process pattern (Ambler, 1998b) which describes the iterative process by which you develop source code. This process pattern shows that code optimization is a part of programming, but only one of many parts. A word of advice that all coders should take to heart.

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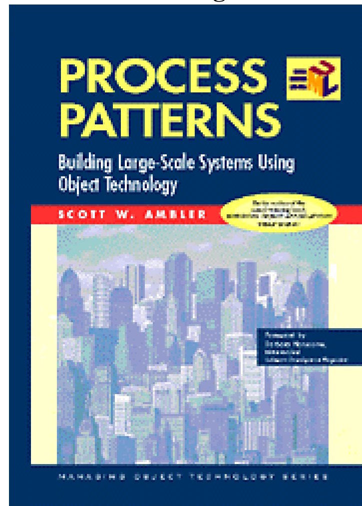
Tip – Define Your Project's Development Priorities

Everybody has their own idea about what is important, and software developers are no different. The issue is that your project, and your organization, needs to define what their development priorities are so that all team members are working to the same vision. Maguire (1994) believes that your organization needs to establish a ranking order for the following factors: size, speed, robustness, safety, testability, maintainability, simplicity, reusability, and portability. These factors define the quality of the software that you produce, and by prioritizing them you will help to define the development goals for your team and will reduce the opportunities for disagreement between your developers.

What should you look for when optimizing code? Koenig (1997) points out that the most important factors are fixed overhead and performance on large inputs. The reason for this is simple: fixed overhead dominates the runtime speed for small inputs and the algorithm dominates for large inputs. His rule of thumb is that a program that works well for both small and large inputs will likely work well for medium-sized inputs.

Developers who have to write software that work on several hardware platforms and/or operating systems need to be aware of idiosyncrasies in the various platforms. Operations that might appear to take a particular amount of time, such as the way that memory and buffers are handled, often show substantial variations between platforms. It is common to find that you need to optimize your code differently depending on the platform.

Blatant Advertising – Purchase *Process Patterns* today!



This book presents a collection of process patterns for successfully initiating a software project and taking it through the construction phase. It provides a wealth of advice for engineering requirements, modeling, programming, and testing. It puts these topics in the context of a proven software process for the development of large-scale, mission-critical software, covering topics that you typically don't find in other books about object-oriented development such as project management, quality assurance, risk management, and deliverables management. Object-oriented development is hard, particularly if you are building systems using n-tier technology such as Enterprise JavaBeans (EJB) or even the "simple" Java platform, and you need to understand the big picture to be successful. *Process Patterns*, and its sister book, *More Process Patterns*, give you that big picture. For more information, and to order online, visit http://www.ambysoft.com/processPatterns.html

Another issue to be aware of when optimizing code is the priorities of your users because depending on the context people will be sensitive to particular delays. For example, your users will likely be happier with a screen that draws itself immediately and then takes eight seconds to load data than with a screen that draws itself after taking five seconds to load data. In other words most users are willing to wait a little longer as long as they're given immediate feedback, important knowledge to have when optimizing your code.

You do not always need to make your code run faster to optimize it in the eyes of your users.

Although optimization may mean the difference between the success and failure of your application, never forget that it is far more important to get your code to work properly. Never forget that slow software that works is almost always preferable to fast software that does not.

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7.4 Writing Java Test Harnesses

Object-oriented testing is critical topic that has been all but ignored by the object development community. The reality is that either you or someone else will have to test the software that you write, regardless of the language that you've chosen to work in. A test harness is the collection of member functions, some embedded in the classes themselves (this is called built-in tests) and some in specialized testing classes, that is used to test your application.

1. **Prefix all testing member function names with 'test'.** This allows you to quickly find all the testing member functions in your code. The advantage of prefixing the name of test member functions with 'test' is that it allows you to easily strip your testing member functions out of your source code before compiling the production version of it.

2. **Name all member function test member functions consistently.** Method testing is the act of verifying that a single member function performs as defined. All member function test member functions should be named following the format '**testMemberFunctionNameForTestName**'. For example, the test harness member functions to test **withdrawFunds()** would include **testWithdrawFundsForInsufficientFunds()** and **testWithdrawFundsForSmallWithdrawal()**. If you have a series of tests for **withdrawFunds()** you may choose to write a member function called **testWithdrawFunds()** that invokes all of them.

3. **Name all class test member functions consistently.** Class testing is the act of verifying that a single class performs as defined. All class test member functions should be named following the format '**testSelfForTestName**'. For example, the test harness member functions to test the Account class **testSelfForSimultaneousAccess()** and **testSelfForReporting()**.

4. **Create a single point for invoking the tests for a class.** Develop a static member function called **testSelf()** that invokes all class testing and method testing member functions.

5. **Document your test harness member functions.** The documentation should include a description of the test as well as the expected results of the test. If you choose to document your tests in an external document, such as a master test/QA plan (Ambler, 1998b; Ambler, 1999) then refer to the appropriate section of that plan in your source code documentation to support traceability.

Further Reading In Object-Oriented Testing

If you're interested in learning more about object-oriented testing then you're in luck because I've written a fair bit on the topic. I started with something called Full Lifecycle Object-Oriented Testing (Ambler, 1998a; Ambler, 1998b; Ambler, 2000d), also known as FLOOT, and evolved this work into the Test In the Small process pattern (Ambler, 1998b) and the Test In The Large process pattern (Ambler, 1999). I've also set up a testing reading list, *http://www.ambysoft.com/booksTesting.html*, within my online bookstore that you'll find useful as well as provided several links to testing and quality assurance related sites at The Process Patterns Page (*http://www.ambysoft.com/processPatternsPage.html*).

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8. The Secrets of Success

The good news is that the reason why I wrote this white paper is because I want to help make Java developers more productive. The bad news is that having a standards document in your possession doesn't automatically make you more productive as a developer. To be successful you must choose to become more productive, and that means you must apply these standards effectively.

8.1 Using These Standards Effectively

The following words of advice will help you to use the Java coding standards and guidelines described in this white paper more effectively:

1. **Understand the standards.** Take the time to understand why each standard and guideline leads to greater productivity. For example, do not declare each local variable on its own line just because I told you to, do it because you understand that it increases the understandability of your code.

2. **Believe in them.** Understanding each standard is a start, but you also need to believe in them too. Following standards shouldn't be something that you do when you have the time, it should be something that you always do because you believe that this is the best way to code. It has been years since I have had to do an "all-nighter" writing code, in most part because I make it a point to use tools and techniques that make me a productive developer. I believe in following standards because it has been my experience that intelligent standards applied appropriately lead to significant increases in my productivity as a developer.

3. **Follow them while you are coding, not as an afterthought.** Documented code is easier to understand while you are writing it as well as after it is written. Consistently named member functions and fields are easier to work with during development as well as during maintenance. Clean code is easier to work with during development and during maintenance. The bottom line is that following standards will increase your productivity while you are developing as well as make your code easier to maintain (hence making maintenance developers more productive too). I have seen too many people write sloppy code while they are developing, and then spend almost as long cleaning it up at the end so that it will pass inspection. That is stupid. If you write clean code right from the beginning you can benefit from it while you are creating it. That is smart.

4. **Make them part of your quality assurance process.** Part of a code inspection should be to ensure that source code follows the standards adopted by your organization. Use standards as the basis from which you train and mentor your developers to become more effective.

5. **Adopt the standards that make the most sense for you.** You do not need to adopt every standard at once, instead start with the ones that you find the most acceptable, or perhaps the least unacceptable, and then go from there. Bring standards into your organization in stages, slowly but surely.

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8.2 Other Factors That Lead to Successful Code

I'd like to share several techniques with you from *Building Object Applications That Work* (Ambler, 1998a) that, in addition to following standards, lead to greater productivity:

1. **Program for people, not the machine.** The primary goal of your development efforts should be that your code is easy for other people to understand. If no one else can figure it out, then it isn't any good. Use naming conventions. Document your code. Paragraph it.

2. **Design first, then code.** Have you ever been in a situation where some of the code that your program relies on needs to be changed? Perhaps a new parameter needs to be passed to a member function, or perhaps a class needs to be broken up into several classes. How much extra work did you have to do to make sure that your code works with the reconfigured version of the modified code? How happy were you? Did you ask yourself why somebody didn't stop and think about it first when he or she originally wrote the code so that this didn't need to happen? That they should have DESIGNED it first? Of course you did. If you take the time to figure out how you are going to write your code before you actually start coding you'll probably spend less time writing it. Furthermore, you'll potentially reduce the impact of future changes on your code simply by thinking about them up front.

3. **Develop in small steps.** I have always found that developing in small steps, writing a few member functions, testing them, and then writing a few more member functions is often far more effective than writing a whole bunch of code all at once and then trying to fix it. It is much easier to test and fix ten lines of code than 100, in fact, I would safely say that you could program, test, and fix 100 lines of code in ten 10-line increments in less than half the time than you could write a single one-hundred line block of code that did the same work. The reason for this is simple. Whenever you are testing your code and you find a bug you almost always find the bug in the new code that you just wrote, assuming of course that the rest of the code was pretty solid to begin with. You can hunt down a bug a lot faster in a small section of code than in a big one. By developing in small incremental steps you reduce the average time that it takes to find a bug, which in turn reduces your overall development time.

4. **Read, read, read.** This industry moves far too quickly for anyone to sit on their laurels. In fact, friends of mine within Sun estimate that it's a full time job for two to three people just to keep up with what's happening with Java, let alone what's happening in the object-orientation field or even development in general. That says to me that you need to invest at least some time trying to keep up. To make things easier for you, I've created an online reading list indicating what I consider to be the key development books that you should consider reading.

Scott's Suggested Reading List: An Online Bookstore

Visit *http://www.ambysoft.com/books.html* for a collection of reading lists for key topics in software development, including Java, patterns, object-orientation, and the software process. Through the Amazon.com Associates program I've set it up so that you can order the books that you want right on the spot. It's as easy as clicking on the cover of the book that you want.

5. **Work closely with your users.** Good developers work closely with their users. Users know the business. Users are the reason why developers create systems, to support the work of users. Users pay the bills, including the salaries of developers. You simply can't develop a successful system if you do not understand the needs of your users, and the only way that you can understand their needs is if you work closely with them.

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6. **Keep your code simple.** Complex code might be intellectually satisfying to write but if other people can't understand it then it isn't any good. The first time that someone, perhaps even you, is asked to modify a piece of complex code to either fix a bug or to enhance it chances are pretty good that the code will get rewritten. In fact, you've probably even had to rewrite somebody else's code because it was too hard to understand. What did you think of the original developer when you rewrote their code, did you think that person was a genius or a jerk? Writing code that needs to be rewritten later is nothing to be proud of, so follow the KISS rule: Keep it simple, stupid.

7. **Learn common patterns, antipatterns, and idioms.** There is a wealth of analysis, design, and process patterns and antipatterns, as well as programming idioms, available to guide you in increasing your development productivity. My experience [Ambler, 1998b] is that patterns provide the opportunity for very high levels of reuse within your software development projects. For more information, visit The Process Patterns Resource Page (*http://www.ambysoft.com/processPatternsPage.html*) for links to key patterns resources and process-oriented web sites.

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9. Proposed javadoc Tags for Member Functions

From the discussions about documentation in this white paper it should be clear that *javadoc* needs a few more tags. While I grant that it is important to keep *javadoc* simple, at the same time it also needs to be sufficient for the task at hand. As a result, I wish to propose the following new tags that I hope will be supported in a future version of *javadoc*.

Proposed Tag	Used for	Purpose
@bug description	Classes, Member Functions	Describes a known bug with the class or member function. One tag per bug should be used.
@concurrency description	Classes, Member Functions, Fields	Describes the concurrency strategy/approach taken by the class/member function/field. The execution context for a member function should be described at this point.
@copyright year description	Classes	Indicates that a class is copyrighted, the year that it was copyrighted in, and any descriptive information such as the name of the individual/organization that holds the copyright.
@example description	Classes, Member Functions, Fields	Provides one or more examples of how to use a given class, member function, or field. This helps developers to quickly understand how to use your classes.
@fyi description	Classes, Interfaces Member Functions, Fields	Provides information about design decisions that you have made and/or good things to know about parts of your code.
@history description	Classes, Member Functions	Describes how a class/member function has been modified over time. For each change, the description should include: who made it, when it was made, what was done, why it was done, and a reference to the change request and/or user requirement that resulted in it.
@modifies no	Member Functions	Indicates that a member function does not modify an object
@modifies yes description	Member Functions	Indicates that a member function modifies an object and describes how it does so.
@postcondition description	Member Functions	Describes a postcondition that is true after a member function has been invoked. Use one tag per postcondition.
@precondition description	Member Functions	Describes a precondition that must be true before the member function can be safely invoked. Use one tag per precondition.
@reference description	Classes, Interfaces, Member Functions, Fields	Describes a reference to an external document that documents pertinent business rules or information that is relevant to the source code being documented.
@values	Fields	Describes the possible values of a field, including ranges and/or distinct values.

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Since I originally wrote this section of the document, Sun has introduced something called "doclets" which give you the ability to extend javadoc (i.e. add new tags). For more information about doclets, and about any proposed new tags, please refer to the information posted at http://java.sun.com about javadoc.

10. Where To Go From Here

This paper is a really good start at understanding how to write robust Java code, but if you truly want to become a superior Java programmer then I highly suggest reading the book *The Elements of Java Style* (Vermeulen et. al., 2000). This book presents a wider range of guidelines than what is presented here in this paper, and more importantly presents excellent source code examples. This paper was combined with Rogue Wave's internal coding standards and then together were evolved to become *The Elements of Java Style*, so you should find the book to be an excellent next step in your learning process. Visit http://www.ambysoft.com/elementsJavaStyle.html for more details.

10.1 Creating Your Own Internal Corporate Guidelines?

10.1.1 Using This PDF File

This file is copyrighted.
You are welcome to use this file, in its entirety, free of charge for the following purposes:

- Your own personal learning experience.
- Your organization's internal use as either a corporate guideline or as a reference document.

10.1.2 Obtaining the Source Document for This File

The source, in Microsoft Word format, is for sale for $1,000 US. If your organization is writing its own internal guidelines, specific to your own environment, then you should seriously consider using this document from a base from which to start. For details email scott@ambysoft.com

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11. Summary

In this white paper we discussed many standards and guidelines for Java developers. Because this white paper is reasonably large I have summarized them here for your convenience. I highly suggest reprinting the pages of this chapter and pinning them on the wall of your workspace so that they are at your fingertips.

This chapter is organized into several one-page summaries of our Java coding standards, collected by topic. These topics are:

- Java naming conventions
- Java documentation conventions
- Java coding conventions

Before we summarize the rest of the standards and guidelines described in this white paper, I would like to reiterate the prime directive:

> **When you go against a standard, document it.** All standards, except for this one, can be broken. If you do so, you must document why you broke the standard, the potential implications of breaking the standard, and any conditions that may/must occur before the standard can be applied to this situation.

A good developer knows that there is more to development than programming.

A great developer knows that there is more to development than development.

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11.1 Java Naming Conventions

With a few exceptions discussed below, you should always use full English descriptors when naming things. Furthermore, you should use lower case letters in general, but capitalize the first letter of class names and interface names, as well as the first letter of any non-initial word.

General Concepts:

- Use full English descriptors
- Use terminology applicable to the domain
- Use mixed case to make names readable
- Use short forms sparingly, but if you do so then use them intelligently
- Avoid long names (less than 15 characters is a good idea)
- Avoid names that are similar or differ only in case

Item	Naming Convention	Example
Arguments/ parameters	Use a full English description of value/object being passed, possibly prefixing the name with 'a' or 'an.' The important thing is to choose one approach and stick to it.	**customer**, **account**, - or - **aCustomer**, **anAccount**
Fields/ fields/ properties	Use a full English description of the field, with the first letter in lower case and the first letter of any non-initial word in uppercase.	**firstName**, **lastName**, **warpSpeed**
Boolean getter member functions	All boolean getters must be prefixed with the word 'is.' If you follow the naming standard for boolean fields described above then you simply give it the name of the field.	**isPersistent()**, **isString()**, **isCharacter()**
Classes	Use a full English description, with the first letters of all words capitalized.	**Customer**, **SavingsAccount**
Compilation unit files	Use the name of the class or interface, or if there is more than one class in the file than the primary class, prefixed with '.java' to indicate it is a source code file.	**Customer.java**, **SavingsAccount.java**, **Singleton.java**
Components/ widgets	Use a full English description which describes what the component is used for with the type of the component concatenated onto the end.	**okButton**, **customerList**, **fileMenu**
Constructors	Use the name of the class.	**Customer()**, **SavingsAccount()**
Destructors	Java does not have destructors, but instead will invoke the **finalize()** member function before an object is garbage collected.	**finalize()**
Exceptions	It is generally accepted to use the letter 'e' to represent exceptions.	**e**
Final static fields (constants)	Use all uppercase letters with the words separated by underscores. A better approach is to use final static getter member functions because it greatly increases flexibility.	**MIN_BALANCE**, **DEFAULT_DATE**

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Java Naming Conventions Continued

Item	Naming Convention	Example
Getter member functions	Prefix the name of the field being accessed with 'get.'	**getFirstName()**, **getLastName()**, **getWarpSpeeed()**
Interfaces	Use a full English description describing the concept that the interface encapsulates, with the first letters of all words capitalized. It is customary to postfix the name with either 'able,' 'ible,' or 'er' but this is not required.	**Runnable**, **Contactable**, **Prompter**, **Singleton**
Local variables	Use full English descriptions with the first letter in lower case but do not hide existing fields/fields. For example, if you have a field named 'firstName' do not have a local variable called 'firstName.'	**grandTotal**, **customer**, **newAccount**
Loop counters	It is generally accepted to use the letters **i**, **j**, or **k**, or the name '**counter**.'	**i**, **j**, **k**, **counter**
Packages	Use full English descriptions, using mixed case with the first letter of each word in uppercase, everything else in lower case. For global packages, reverse the name of your Internet domain and concatenate to this the package name.	**java.awt**, **com.ambysoft.www. persistence.mapping**
Member Functions	Use a full English description of what the member function does, starting with an active verb whenever possible, with the first letter in lower case.	**openFile()**, **addAccount()**
Setter member functions	Prefix the name of the field being accessed with 'set'.	**setFirstName()**, **setLastName()**, **setWarpSpeed()**

Although I do not agree with the following conventions, Sun suggests that for local variables of the given types you can give them short names. A much better convention is to use a full English descriptor – Do not be lazy.

Variable Type	Suggested Naming Convention
offset	**off**
length	**len**
byte	**b**
char	**c**
double	**d**
float	**f**
long	**l**
Object	**o**
String	**s**
Arbitrary value	**v**

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11.2 Java Documentation Conventions

A really good rule of thumb to follow regarding documentation is to ask yourself if you've never seen the code before, what information would you need to effectively understand the code in a reasonable amount of time.

General Concepts:

- Comments should add to the clarity of your code
- If your program isn't worth documenting, it probably isn't worth running
- Avoid decoration, i.e. do not use banner-like comments
- Keep comments simple
- Write the documentation before you write the code
- Document why something is being done, not just what

11.2.1 Java Comment Types

The following chart describes the three types of Java comments and suggested uses for them.

Comment Type	Usage	Example
Documentation	Use documentation comments immediately before declarations of interfaces, classes, member functions, and fields to document them. Documentation comments are processed by *javadoc*, see below, to create external documentation for a class.	/** Customer – A customer is any person or organization that we sell services and products to. @author S.W. Ambler */
C style	Use C-style comments to document out lines of code that are no longer applicable, but that you want to keep just in case you users change their minds, or because you want to temporarily turn it off while debugging.[10]	/* This code was commented out by J.T. Kirk on Dec 9, 1997 because it was replaced by the preceding code. Delete it after two years if it is still not applicable. . . . (the source code) */

Single line	Use single line comments internally within member functions to document business logic, sections of code, and declarations of temporary variables.	// Apply a 5% discount to all invoices
		// over $1000 as defined by the Sarek
		// generosity campaign started in
		// Feb. of 1995.

[10] This isn't actually a standard, it's more of a guideline. The important thing is that your organization should set a standard as to how C-style comments and single-line comments are to be used, and then to follow that standard consistently.

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11.2.2 What To Document

The following chart summarizes what to document regarding each portion of Java code that you write.

Item	What to Document
Arguments/ parameters	The type of the parameter What it should be used for Any restrictions or preconditions Examples
Fields/ fields/properties	Its description Document all applicable invariants Examples Concurrency issues Visibility decisions
Classes	The purpose of the class Known bugs The development/maintenance history of the class Document applicable invariants The concurrency strategy
Compilation units	Each class/interface defined in the class, including a brief description The file name and/or identifying information Copyright information
Getter member function	Document why lazy initialization was used, if applicable
Interfaces	The purpose How it should and shouldn't be used
Local variables	Its use/purpose
Member Functions – Documentation	What and why the member function does what it does What a member function must be passed as parameters What a member function returns Known bugs Any exceptions that a member function throws Visibility decisions How a member function changes the object Include a history of any code changes Examples of how to invoke the member function if appropriate Applicable preconditions and postconditions Document all concurrency
Member Functions – Internal comments	Control structures Why, as well as what, the code does Local variables Difficult or complex code The processing order
Package	The rationale for the package The classes in the package

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11.3 Java Coding Conventions (General)

There are many conventions and standards which are critical to the maintainability and enhancability of your Java code. 99.9% of the time it is more important to program for people, your fellow developers, than it is to program for the machine. Making your code understandable to others is of utmost importance.

Convention Target	Convention
Accessor member functions	Consider using lazy initialization for fields in the database Use accessors for obtaining and modifying all fields Use accessors for 'constants" For collections, add member functions to insert and remove items Whenever possible, make accessors protected, not public
Fields	Fields should always be declared private Do not directly access fields, instead use accessor member functions Do not use final static fields (constants), instead use accessor member functions Do not hide names Always initialize static fields
Classes	Minimize the public and protected interfaces Define the public interface for a class before you begin coding it Declare the fields and member functions of a class in the following order: • constructors • **finalize()** • public member functions • protected member functions • private member functions • private field
Local variables	Do not hide names Declare one local variable per line of code Document local variables with an endline comment Declare local variables immediately before their use Use local variables for one thing only
Member Functions	Document your code Paragraph your code Use whitespace, one line before control structures and two before member function declarations A member function should be understandable in less than thirty seconds Write short, single command lines Restrict the visibility of a member function as much as possible Specify the order of operations

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Glossary

100% pure – Effectively a “seal of approval” from Sun that says that a Java applet, application, or package, will run on ANY platform which supports the Java VM.

Accessor – A member function that either modifies or returns the value of a field. Also known as an access modifier. See getter and setter.

Analysis pattern – A modeling pattern that describes a solution to a business/domain problem.

Antipattern – An approach to solving a common problem, an approach that in time proves to be wrong or highly ineffective.

Argument – See parameter.

Attribute – A variable, either a literal data type or another object, that describes a class or an instance of a class. Instance fields describe objects (instances) and static fields describe classes. Fields are also referred to as fields, field variables, and properties.

BDK – Beans development kit.

Block – A collection of zero or more statements enclosed in (curly) braces.

Braces – The characters **{** and **}**, known as an open brace and a close brace respectively, are used to define the beginning and end of a block. Braces are also referred to as ‘curlies’ (do not ask).

Class – A definition, or template, from which objects are instantiated.

Class testing – The act of ensuring that a class and its instances (objects) perform as defined.

Compilation unit – A source code file, either a physical one on disk or a “virtual” one stored in a database, in which classes and interfaces are declared.

Component – A user interface item such as a list, button, or window.

Constant getter – A getter member function which returns the value of a “constant,” which may in turn be hard coded or calculated if need be.

Constructor – A member function which performs any necessary initialization when an object is created.

Containment – An object contains other objects that it collaborates with to perform its behaviors. This can be accomplished either the use of inner classes (JDK 1.1+) or the aggregation of instances of other classes within an object (JDK 1.0+).

CPU – Central processing unit.

C-style comments – A Java comment format, /* … */, adopted from the C/C++ language that can be used to create multiple-line comments. Commonly used to “document out” unneeded or unwanted lines of code during testing.

Design pattern – A modeling pattern that describes a solution to a design problem.

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Destructor – A C++ class member function that is used to remove an object from memory once it is no longer needed. Because Java manages its own memory, this kind of member function is not needed. Java does, however, support a member function called **finalize()** that is similar in concept.

Documentation comments – A Java comment format, /** … */, that can be processed by *javadoc* to provide external documentation for a class file. The main documentation for interfaces, classes, member functions, and fields should be written with documentation comments.

Field – See attribute.

finalize() – A member function that is automatically invoked during garbage collection before an object is removed from memory. The purpose of this member function is to do any necessary cleanup, such as the closing of open files.

Garbage collection – The automatic management of memory where objects that are no longer referenced are automatically removed from memory.

Getter – A type of accessor member function that returns the value of a field. A getter can be used to answer the value of a constant, which is often preferable to implementing the constant as a static field because this is a more flexible approach.

HTML – Hypertext markup language, an industry-standard format for creating web pages.

Indenting – See paragraphing.

Inline comments – The use of a line comment to document a line of source code where the comment immediate follows the code on the same line as the code. Single line comments are typically used for this, although C-style comments can also be employed.

Interface – The definition of a common signature, including both member functions and fields, which a class that implements an interface must support. Interfaces promote polymorphism by composition.

I/O – Input/output.

Invariant – A set of assertions about an instance or class that must be true at all "stable" times, the periods before and after the invocation of a member function on the object/class.

Java – An industry-standard object-oriented development language that is well-suited for developing applications for the Internet and applications that must operate on a wide variety of computing platforms.

javadoc – A utility included in the JDK that processes a Java source code file and produces an external document, in HTML format, describing the contents of the source code file based on the documentation comments in the code file.

JDK – Java development kit.

Lazy initialization – A technique in which a field is initialized in its corresponding getter member function the first time that it is needed. Lazy initialization is used when a field is not commonly needed and it either requires a large amount of memory to store or it needs to be read in from permanent storage.

Local variable – A variable that is defined within the scope of a block, often a member function. The scope of a local variable is the block in which it is defined.

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Master test/quality assurance(QA) plan – A document that describes your testing and quality assurance policies and procedures, as well as the detailed test plans for each portion of your application.

Member Function – A piece of executable code that is associated with a class, or the instances of a class. Think of a member function as the object-oriented equivalent of a function.

Member function signature – See signature.

Method testing – The act of ensuring that a member function (method) performs as defined.

Modeling pattern – A pattern depicting a solution, typically in the form of a class model, to a common modeling problem.

Name hiding – This refers to the practice of using the same, or at least similar, name for a field/variable/argument as for one of higher scope. The most common abuse of name hiding is to name a local variable the same as an instance field. Name hiding should be avoided as it makes your code harder to understand and prone to bugs.

Overload – A member function is said to be overloaded when it is defined more than once in the same class (or in a subclass), the only difference being the signature of each definition.

Override – A member function is said to be overridden when it is redefined in a subclass and it has the same signature as the original definition.

Package – A collection of related classes.

Paragraphing – A technique where you indent the code within the scope of a code block by one unit, usually a horizontal tab, so as to distinguish it from the code outside of the code block. Paragraphing helps to increase the readability of your code.

Parameter – An argument passed to a member function. A parameter may be a defined type, such as a string or an int, or an object.

Pattern – The description of a general solution to a common problem or issue from which a detailed solution to a specific problem may be determined. Software development patterns come in many flavors, including but not limited to analysis patterns, design patterns, and process patterns.

Postcondition – A property or assertion that will be true after a member function is finished running.

Precondition – A constraint under which a member function will function properly.

Process pattern – A pattern that describes a proven, successful approach and/or series of actions for developing software.

Property – See field.

Quality assurance (QA) – The process of ensuring that the efforts of a project meet or exceed the standards expected of them.

Setter – An accessor member function that sets the value of a field.

Signature – The combination of the type of parameters, if any, and their order that must be passed to a member function. Also called the member function signature.

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Single-line comments – A Java comment format, // … , adopted from the C/C++ language that is commonly used for the internal member function documentation of business logic.

Tags – A convention for marking specified sections of documentation comments that will be processed by *javadoc* to produce professional-looking comments. Examples of tags include @*see* and @*author*.

Test harness – A collection of member functions for testing your code

UML – Unified modeling language, an industry standard modeling notation.

Visibility – A technique that is used to indicate the level of encapsulation of a class, member function, or field. The keywords public, protected, and private can be used to define visibility.

Whitespace – Blank lines, spaces, and tabs added to your code to increase its readability.

Widget – See component.

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13. Index

@

@author tag 5
@concurrency tag (proposed) 53
@deprecated tag 5
@example tag (proposed) 53
@exception tag 5
  usage 10
@fyi tag (proposed) 53
@history tag (proposed) 53
@modifies tag (proposed) 53
@param tag 5
  usage 10
@postcondition tag (proposed) 53
@precondition tag (proposed) 53
@return tag 5
  usage 10
@see tag 5
@since tag 5
@version tag 5

1

100% pure
  definition 62

A

Abbreviation
  usage 2
Accessor member function 22
  advantages and disadvantages 29
  constant getters 25
  definition 62
  for collections 27
  getters 7
  overhead of 22
  setter member functions 8
  visibility 28
Acronym
  naming convention 2, 17
Ambler's Law of Standards 6
Analysis pattern 62
Analysis patterns 37
Antipattern 62
Antipatterns 52
Architecture 37
Argument .... *See* parameter
Assertions 6
Attribute
  accessors 22, 23
  and lazy initialization 24
  definition 62
  documenting 22
  getter 23
  getter member functions 22
  initialization 24
  name hiding 20
  naming conventions 17
  setter 23
  setter member functions 22
  visibility 21
Author
  contacting 68

B

Banner comments 3
BDK 62
Block
  definition 62
Book
  Elements of Java Style 6, 13, 37
  Process Patterns 30, 47
Braces
  definition 62
  documentation of 13

C

Class 36
  definition 62
  documentation conventions 37
  naming conventions 36
Class testing 62
Clean code 13
Code clarity 3
Code history 10
Code inspections 50
Coding standards
  classes 36
  compilation units 44
  for local variables 31
  for member functions 7
  importance of 1
  interfaces 41
  packages 42
  parameters 34
  using them effectively 50
Collections
  accessor member functions 27
Comments

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banner style 3
in member functions 9
types of........ 4
Compilation unit
coding standards 44
definition 62
documentation conventions 44
naming conventions........ 44
Complex code........ 12
Component
definition 62
naming conventions........ 18
Component design........ 36
Concurrency........ 6
and setter member functions........ 29
documentation of........ 11, 22, 37
notifyAll 29
Constant getter........ 25
definition 62
Constants
naming conventions........ 19
Constructor
definition 62
Containment
definition 62
Control structures 11
Copyright........ 55
Corporate guidelines........ 55
Coupling
and accessors 29
and inheritance........ 29
C-style comments 4
definition 63
usage........ 11

D

Databases 37
Default visibility 9
Design first........ 51
Design pattern 63
Design patterns 37
Destructor
definition 63
Develop in small steps........ 51
Distributed design........ 37
doclets........ 55
Documentation
clarity 3
code history 10
concurrency........ 11, 22
internal........ 11
of attributes........ 22
of closing braces 13
of complex code........ 12
of local variables 33
of member functions........ 9
of processing order........ 12
overview........ 3
parameters 35
why........ 3, 9
Documentation comments 4
definition 63
Documentation conventions
classes 37
compilation units........ 44
interfaces 41
packages........ 42

E

Encapsulation
and accessor member functions 29
End of line comments........ 4
Endline comment........ 13, 15, 33
Endline comments 4
English descriptors 2
Example source code........ 6
Exception handling........ 6
Exception objects 32
Extreme Programming........ 13

F

Field .... *See* attribute
finalize() member function
definition 63
FLOOT 13, 49
Fragile base class problem........ 29
Friendly visibility........ *See* package visibility
Full Lifecycle Object-Oriented Testing........ 13, 49

G

Garbage collection
definition 63
Getter member function 22
advantages and disadvantages 29
and lazy initialization 24
definition 63
for constants........ 25
naming conventions........ 7, 23

H

HTML
definition 63
Hungarian notation........ 17
postfix........ 18
prefix........ 18

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I

Idioms 52
Indenting .... *See* paragraphing
Inheritance
  coupling 29
Inline comments
  definition 63
  disadvantages 4
Interface 41
  definition 63
  documentation convention 41
  naming conventions 41
Invariant
  definition 63
  documentation of 37

J

Java
  definition 63
javadoc 5
  and member functions 10
  definition 63
  doclets 55
  proposed tags 53
  tags 5
javadoc tags .... *See* tags
JDK 64

K

KISS 52

L

Lazy initialization 24
  definition 64
  documentation 24
Local variable
  coding standards 31
  declaring 33
  definition 64
  documentation of 11
  documenting 33
Long names 2
Loop counters 31

M

Maintenance
  and parenthesis 15
  cost of 1
Master test/QA plan 64
Member Function
  accessors 22
  coding standards 7
  definition 64
  documentation 9
  getter 22
  internal documentation 11
  setter 22
  visibility 9
Member Function signature .... *See* signature
Metrics 37
Mixed case 2
Modeling pattern 64
Multi-line statements 14
Mutator ..... *See* Setter member function. *See* setter

N

Name hiding 20
  definition 64
Naming conventions
  accessor member functions 23
  accessors 7
  attributes 17
  classes 36
  compilation units 44
  components 18
  constants 19
  exception objects 32
  for parameters 34
  getter member functions 7, 23
  hungarian notation 18
  interfaces 41
  local variables 31
  loop counters 31
  member functions 7
  overview 2
  packages 42
  setter member functions 8, 23
  streams 31
notifyAll 29

O

Object databases 37
Object-Oriented Software Process 13
OOSP 13
Optimization
  and portability 47
  factors 47
  leave to end 46
Order of operations 15
Overload
  definition 64
Override
  definition 64

P

Package 42

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definition 64
documentation conventions 42
naming conventions 42
Package visibility 9, 36
Paragraphing 14
definition 64
Parameter
definition 64
documentation conventions 35
documentation of 10
naming convention 34
Parameters 34
Pattern 64
Patterns 52
Plan
master test/QA plan 64
Portability
and optimization 47
Postcondition
definition 64
documentation of 10
Precondition
definition 65
documentation of 10
Prime Directive 1
Private visibility 9
Process pattern 65
Process Patterns Resource Page 52
Processing order
documentation of 12
Property .... *See* attribute
Protected visibility 9
Public interface
of a class 40
Public visibility 9, 36
Punch cards 15
Punctuation
multi-line statements 14

Q

Quality assurance 50
Quality assurance (QA) 65

R

Relational databases 37

S

Scott Ambler
contacting 68
Setter member function 22
advantages and disadvantages 29
definition 65
naming conventions 8, 23
Short forms 2, 57
Signature
definition 65
Single letter names 31
Single-line comments 4
definition 65
usage 11
Standard
Ambler's law 6
Static initializers 30
Streams 31
Synchronization 6

T

Tags 5
definition 65
proposed 53
Test harnesses 49
Test In The Large 49
Test In The Small 49
Testing 49
class testing 62
method testing 64
Thirty-second rule 15
Tips
access to attributes 23
beware endline comments 4
define the public interface first 40
define your priorities 47
document closing braces 13
set component naming standards 19
use interfaces for parameter types 35
Traceability 49
Type safety 6

U

UML 65
Underscores 18
Unified Modeling Language 13
Unified Process 13
Users
working closely with 51

V

Visibility
definition 65
of accessor member functions 28
of attributes 21
of member functions 9

W

Whitespace 15
definition 65

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Why
documentation of... 3, 11
Widget ....*See* component

X

XP 13