Designing Software for Reuse

Will Tracz

IBM FSD
MD 0210
Owego, NY 13827

OWEGO@IBM.COM
(607) 751 - 2169

11/7/90

Software Engineering Professional Education Center
University of Houston-Clear Lake
2700 Bay Area Blvd., Box 258
Houston, Texas  77058
Designing Software for Reuse

Will Tracz

IBM FSD
MD 0210
Owego, NY 13827

OWEGO@IBM.COM
(607) 751-2169

11/7/90

---

Designing Software for Reuse

Outline

- Terminology
- Mindset – Maxims
- The Big Picture
- The 3-C Model
- Science of Programming
- Interface Design Example
- Modularization Example
- Reuse and Implementation Guidelines
Software Reuse
Definitions

- Use
- Reuse
- Useability
- Reusability

Software Reuse
 Definitions

- Software Reuse
- Software Salvaging
- Carry–over Code
- Reusable Software
- Software Reusability
**Software Reuse**

*Definitions (Webster)*

- **Use**: the act of employing something.
- **Reuse**: further or repeated use.
- **Usability**: having utility.
- **Reusability**: a property that supports reuse.
Definition #2
Software Reuse

Using existing software

- across time – maintenance
- across environments – porting
- across applications – adaptability

Definition
Software Salvaging

The process of locating, extracting and possible modifying software from an existing application for use in a new application.

(new application)
**Definition**

**Carry-over Code**

Code that is kept (reused) from one version of an application to another.

*(same application)*

---

**Definition**

**Reusable Software**

Software that was designed to be reused.

*(new application)*
**Definition**

Software Reusability

The degree to which software can be reused for different applications.

- **Vertical**: within one application domain.
- **Horizontal**: across application domains.

**Software Reuse**

**Terminology**

- Black Box vs Clear Box
- Primitive vs Composite
- Simple vs Tailorable
- Template – Skeleton – Frame
- Generic – Macro
Reuse is..

Something you do all the time.

Not something new.

Not something you always plan on doing.

Not something you always plan on doing again.

Not something we do all the time.

Definitions
Taxonomy

1. Unplanned Reuse
   • Re-hosting
   • Maintenance
   • Salvaging

2. Planned Reuse
   • Portability
   • Adaptability
   • Modularity
Software Reuse
Current Approaches

1. Passive — Composition Technology
2. Active — Generation Technology

A Framework for Reusability Technologies

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>APPROACHES TO REUSABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPONENT REUSED</td>
<td>BUILDING BLOCKS</td>
</tr>
<tr>
<td>NATURE OF COMPONENT</td>
<td>ATOMIC AND IMMUTABLE</td>
</tr>
<tr>
<td></td>
<td>DIFFUSE AND MALLEABLE</td>
</tr>
<tr>
<td>PRINCIPLE OF REUSE</td>
<td>COMPOSITION</td>
</tr>
<tr>
<td>EMPHASIS</td>
<td>APPLICATION COMPONENT LIBRARIES</td>
</tr>
<tr>
<td></td>
<td>LANGUAGE BASED GENERATORS</td>
</tr>
<tr>
<td>TYPICAL SYSTEMS</td>
<td>LIBRARIES OF SUBROUTINES</td>
</tr>
</tbody>
</table>
Active Approaches to Reuse
Generation Technology

- Macros
- Generics
- Pre-Processors
- Application Generators
- 4th Generation Languages
- Parameterized Programming
- Frame-Based Programming
- Generic Architectures/Domain Models
- Constructors (Expert Systems)

Formal Approaches to Reuse
Theory

- Type Theory
- Lambda Calculus
- Conceptual Model for Reusable SW Components:
  - Separate Concept from Context.
  - Separate Concept from Content.
  - Isolate change (context) via parameters.
Software Reuse Maxims
A Perspective on Software Reuse

- Motivation
- Inspiration
- Education

Software Reuse Maxims
Golden Rules of Reusability

Before you can reuse something, you need to

1. find it,

2. know what it does, and

3. know how to reuse it.
Software Reuse Maxims

Rules of Three

1. Before you can develop reusable software you need to have used it *three* times.

2. Before you can reap the benefits of reuse, you need reuse it at least *three* times.

Software Reuse will become the *Expert Systems* of the 1990's.
Software Reuse Maxims

Software Reuse is like a savings account before you can collect any interest, you need to make a deposit, and the larger the deposit, the larger the dividend.

The Reuse Mindset

Problem: design and implement a Stack

FORTRAN Mindset: an array

PASCAL Mindset: a linked list

Basic Ada Mindset: a package

Experienced Ada Mindset: a generic package

Advanced Ada Mindset: a family of generic packages
Software Reuse Maxims

Software Reuse: The Search for Elegance.

Why is there never enough money to do the job right?

BUT

Always enough to do it over?
Software Reuse Maxims

What sets reusable software *apart*

is

How it is *put together*.

Software Reuse Maxims

When your *object is Reusable Software*

you need a *methodology*

to support it.
Software Reuse Maxims

When you design your software

Top Down

but implement your software

Bottom Up

sometimes it doesn’t meet in the middle.

Software Reuse Maxims

For instance

Reusable Software Engineers

inherently do it with

class.
Software Reuse Maxims

Reusable Software:

it's the type of thing that makes it most useful.

Evolution of Types

- Mathematical
- Machine Intrinsic
- Built into language
- User Defined (Abstract) Data Types
- Parameterized Types
- Polymorphic Types
- Type Hierarchies
- Derived Types/Subtypes
Software Reuse Maxims

Reusable Software
has many arguments;
Not Reusable Software
may have too many or too few.

Software Reuse
is the best way to
Reuse Software
again.
Software Reuse Maxims

It's not easy to make a good CASE for Software Reuse

Software Reuse Maxims

Picture this pipe dream:

Today's Menu: *Reuse — Made to order*

Today's Special: *Macroni Shell Script Delight*
Software Reuse Maxims

Have Template

Will Trace!

Software Reuse Maxims

Ask not what you can do for your software but what your software can do for you.
Software Reuse Corollary

What is one question that is never answered NO more than once in a Japanese Software Factory?

Does a part exist that does this function?

Software Reuse Maxims

The most important quality of Reusable Software is that it is quality software.
A Quality Argument

Given a program made up of \( n \) components

What is the probability (\( P \)) that it is correct?

*Assume: the probability each component is correct is 95%*

If \( n = 10 \), \( P = \)

If \( n = 100 \), \( P = \)

Software Reuse Maxims

Software Reuse,

like Quality,

is free.
Software Reuse Maxims

You can make the difference between

Reusable Software

and

Reused Software

Software Reuse Maxims

It's time to move from

Reusable Software

Techniques and Mythology

to

Technology and Methodology
Software Reuse Maxims

*Ad Hack Reuse:*

*Business as*

*Re-usual*

Software Reuse Maxims

*Software Reuse*

is a good example of

Software Engineering discipline.
The Big Picture
The Programming Process (IBM)

1. Requirements
2. Design
3. Implementation
4. Test
5. Package and Validate
6. Availability

The Big Picture
DOD – STD – 2167

1. Requirements Analysis
2. Preliminary Design
3. Detailed Design
4. Coding and Unit Test
5. System Integration Test
6. Production and Deployment
The Big Picture
Software Reuse Technology

1. Domain Analysis
2. Data Encapsulation and Information Hiding
3. Application Generators, 4GLs and gIBIS
4. Object-Oriented Programming Languages
5. Formal/Rigorous Verification
6. Promotion and Sales

Guidelines

The Big Picture
Programming For Reuse

Data
Algorithm
Structure
Dependencies
The Big Picture
Programming Taxonomy

- exploratory
- by difference
- by analogy
- by contracting
- by subcontracting

- for Reuse
- with Reuse
- in the Old
- in the New

The Big Picture
Programming Taxonomy

- in the small
- in the large
- at large
- with the large

- for the many by the many
- for the many by the few
- for the few by the many
- for the few by the few
**Conceptual Model**

**Reusable Software Components**

- Context
- Concepts
- Content
  - Context
  - Concepts
  - Content

**Conceptual Model**

**Context**

- "Language shapes thought"
  - Inheritance
  - Genericity/Parameterization
  - Importation
- Binding time
  - Compile time
  - Load/Bind time
  - Run Time
Conceptual Model

Concepts

- Concept:  - *What*
- Content:  - *How*
- Context:
  1. Conceptual  - *relationship*
  2. Operational  - *with/to what*
  3. Implementation  - *trade-offs*

Context: what is needed to complete the definition of a concept or content within an environment. (*Latour*)

Software Components

Formal Foundations

- Horizontal Structure
  1. type inheritance
  2. code inheritance
- Vertical Structure
  - implementation dependencies
  - virtual interfaces
- Generic Structure
  - variations/adaptations
Conceptual Model

Example

- Concept: Stack
  - Operational Context: Element/Type
  - Conceptual Context: Deque
  - Implementation Context: Sequence

Conceptual Model

Example

- Stack Implementation
  1. Inherit Deque
  2. Use an array
  3. Use a linked-list
     - memory management
     - no memory management
     - concurrent access
**Megaprogramming Example**

Stack $\rightarrow$ Deque

```plaintext
make Deque [ Triv ] is
  Stack [ Triv ]
  * ( rename ( Push = $\rightarrow$ Push_Right )
      ( Pop = $\rightarrow$ Pop_Right )
      ( Stack = $\rightarrow$ Deque )
  * ( add Push_Left, Push_Right )
end;
```

**Hyperprogramming Example**

Make with View

```plaintext
make Integer_Set is
  LIL_Set [ Integer_View ]
end;

view Integer_View :: Triv $\rightarrow$ Standard is
  types ( Element $\rightarrow$ Integer )
end;
```
Megaprogramming Example
Make with Vertical Composition

make Short Stack is
LIL Stack
    -- horizontal composition
needs (List_Theory -> List_Array)
    -- vertical composition
end;

LILEANNA Example
Package Expressions

make New_Ada.Logic_Interface is
    Identifier_Package +
    Clause_Package*(hide Copy) +
    Substitution_Package +
    DataBase_Package +
    Query_Package*[add function Query_Fail (C: Clause;
        L: List_Of_Clauses)
        return Boolean)]
end;
*(rename (Query_Answer -> Query_Results ))
The Science of Programming

David Gries

Springer-Verlag - 1981

- Propositions and Predicate Calculus
- Programming Principles/Strategies
  - Developing the proof along with the program
  - Precondition and Postconditions
  - What to put in formalism or put in English

Programming Principle #1

A Program and its proof should be developed hand-in-hand, with the proof usually leading the way.

- It's too hard to prove an existing program correct.
- Need balance between Formality and Common Sense.
  - Formality alone = > incomprehensible detail.
  - Common sense alone = > allows too many errors.
Programming Principle #2

Use theory to provide insight use common sense and intuition where it is suitable, but fall back on the formal theory for support when difficulties and complexities arise.

- Proof versus Test Case Analysis
- Test cases don’t always give insight
- Don’t Program from Example

Programming Principle #3

Know the properties of the objects that are to be manipulated by the program.

- Data Refinement
- Data Encapsulation
Programming Principle #4

Never dismiss as obvious any fundamental principle, for it is only through conscious application of such principles that success will be achieved.

- Recognize a Principle /= Applying a Principle
- QWERTY style of programming
- One programs into a language, not in it.

Programming Principle #5

Programming is a goal-oriented activity.

- Insight from postcondition
- Abstraction = Simplification/Layers
- Precondition = Interface check
- Prove/Work Backward
Programming Principle #6,#7

Before attempting to solve a problem, make absolutely sure you know what the problem is.

Before developing a program, make precise and refine the pre— and postconditions.

- Specification = What a program is to do.
- Abstraction = Simplification of specification
- Non—Determinism allows greater freedom in design

Programming Principle #8

All other things being equal, make the guards of an alternative command as strong as possible, so that some errors will cause abortion.

- Inline test = Assertion
- Test/document if what you think is valid holds.
Programming Principle #9

All other things being equal, make the guards of a loop as weak as possible, so that an error may cause an infinite loop.

- It takes 3 runs to debug a loop
  1. Once too many
  2. Once too few
  3. Just right
- Establish guards (end points)
- Establish loop invariants

Programming Principle #10

Introduce a variable only when there is a good reason for doing so.

- User optimization?
- What are compilers good at?
- Abstraction
Programming Principle #11

Put suitable bounds on each variable introduced.

- Abstract data type
- Static/Dynamic checking

Programming Principle #12

Introduce a name to denote a value that is to be determined.

- Define *basic concepts* for notation
- Avoid over-specifying
- Methodology = Top-down and Bottom-up
Programming Principle #13

The more guarded commands and the weaker their guards, the easier it may be to develop a correct program.

- Dual paradigm approach
- Develop proof to gain insight into program.

Programming Principle #14

Program into a programming language, not in it.

- Procedural Refinement
- Data Refinement
- Use the data structure that matches the problem.
Programming Principle #15

Keep the number of different cases to a minimum.

- Generalize
- Look for other methods of expression.
- Postpone decisions as late as possible.

Programming Principles Summary

Resolve ambiguities and unknowns at specification time.

Design (and test case analysis) comes before coding.

Program into a programming language, not in it.
Interface Design

Sorting Example

Requirement:

- Implement a Sort Routine

Sorting Example
Missing Specifications

- Sort what kind of data?
  - Predefined (e.g., Integer, Float, ...)
  - User Defined (e.g., record, private)
- Sort what kind of data structure?
  - Array
  - Linked List
  - File

Does it matter?
Sorting Example
Missing Specifications

- What are the environment constraints?
  - OS dependencies
  - Concurrency
  - Error conventions
  - Size of data/exeuction speed
- How is this going to be used?
  - Function or Procedure call
  - Default Parameters
  - Single/multiple data types

Does it matter?

Sorting Example
It Does Matter

- Sort what kind of data?
  - Predefined (e.g., Integer, Float, ...)
    - can assume availability of ":=" and ":<"
  - User Defined (e.g., record)
    - need to know ":=" and ":<" are available
Sorting Example
It Does Matter

- Sort what kind of data structure?
  - Array
    - Can use indexing to access list.
    - What are the indexes?
  - Linked List
    - need way to manipulate data structure
      - Next
      - End
      - Length
    - File

- What are the environment constraints?
  - OS dependencies
    - I/O
  - Concurrency
    - Is data shared?
  - Error conventions
    - Exceptions?
    - Error flag?
    - Formal generic procedure?
    - State of data on error exit?
  - Size of data/execution speed
    - Algorithm
Sorting Example
It Does Matter

- How is this going to be used?
  - Function call
    - Can't Sort in place
    - Could run out of storage
  - Procedure call
    - What should the parameter sequence be?
    - algorithm: election as a parameter?
  - Defaults
    - algorithm?
    - what about generic arguments?
  - Generic
    - how many formats in package?
    - what are the formal parameters?

Sorting Example
Signatures

type D_Str is ...  -- Data Structure

function Bubble_Sort (X: D_Str) return D_Str;

function Quick_Sort (X: D_Str) return D_Str;
Sorting Example

Signatures

type Algorithm is (Bubble_Sort, Quick_Sort);

function Sort (A: Algorithm; X: D_Str)
    return D_Str;

function Sort(X: D_Str;
    A: Algorithm = Bubble_Sort)
    return D_Str;

function Sort (X: D_Str) return D_Str;
    -- Heuristic on size of X

procedure Bubble_Sort(X: in out D_Str);

procedure Bubble_Sort(X_In: in D_Str;
    X_Out: out D_Str);

procedure Bubble_Sort(X_In: in D_Str;
    X_Out: in out D_Str);

procedure Bubble_Sort (X_Out: out D_Str;
    X_In: in D_Str);
Sorting Example

Signatures

procedure Sort ( X: in out D_Str;
A: Algorithm := Bubble_Sort );

Residual Control

procedure Set_Algorithm ( A: Algorithm);
procedure Sort ( X: in out D_Str);

Interface Modification

New Requirements

- Add metrics:
  - Number of comparisons
  - Number of swaps
Interface Modification

Alternatives

• Add two new parameters to each signature
• Add one new parameter to each signature (record)
• Replace Algorithm with Options record
• Add a new operation to report results.
• Add a new operations with new parameters

Interface Modification

Alternatives

• Add two new parameters to each signature
  – Have to change all calls
  – No growth potential
  – Signatures become cluttered
Interface Modification

Alternatives

- Add one new parameter to each signature (record)
  - Have to change all calls
  + Some growth potential
  - What order with other options?

- Replace Algorithm parameter with Options record
  + Growth potential
  - Still have to change all calls
Interface Modification
Alternatives

- Add a new operation to report results.
  + Don't need to change any calls
  + Good growth path
  + Keeps interface clean.
  - Problems in concurrent applications.

Interface Modification
Alternatives

- Add new operations with new parameters
  + Don't need to change any calls
  + Good growth path
  + No problems in concurrent applications.
  - Clutters interface.
Parameterization Conventions

Style

- No functions
- Limit number of parameters
- Operation/option tradeoff
- Residual control/option list tradeoff
- Categorize operations
  - Selectors
  - Constructors
  - Iterators
  - Control

Parameterization Conventions

Parameter Ordering

- Operands appear before options
- in out parameters appear before in parameters
- defaults for control parameters
- options organized as an aggregate (record)
- default option under functional control
Parameterization Conventions

Internal versus External Parameters

- Command line options
- Input options
- Option file
- Input option file name
- Explicit default files for options

Parameterization Conventions

Issues Not Addressed

- Documentation
- Fire walls
- Intelligent defaults
- Application generators
- Expert system guidance
- Polymorphism
Modularization: A Case Study for Reuse in Ada

- **Example:** *deque*
  - Pop/Push/Print

- **Forms**
  - Functions
  - Abstract Data Object
  - Abstract Data Type
  - Parameterized Abstract Data Type

- **Composition Techniques**
  - black box
  - program templates
  - functional composition
  - repackaging

Interface Design

- Naming Conventions
- Use of Global Data
- Types and Number of Parameters
- Use of Functions or Procedures
- Use of Default Values
- Documentation
Functional Decomposition
Procedural Style

package Deque_FD_1 is
  -- declarations for Element_Type and Deque_Type
  procedure Push_Front ( Value : in Element_Type; Deque : in out Deque_Type );
  procedure Push_Rear ( Value : in Element_Type; Deque : in out Deque_Type );
  procedure Pop_Front ( Value : out Element_Type; Deque : in out Deque_Type );
  procedure Pop_Rear ( Value : out Element_Type; Deque : in out Deque_Type );
  procedure Print ( Deque : in Deque_Type );
end Deque_FD_1;

Functional Decomposition
Pure Functional Approach

package Deque_FD_2 is
  -- declarations for Element_Type and Deque_Type
  function Push_Front ( Value : in Element_Type; Deque : in Deque_Type ) return Deque_Type;
  function Push_Rear ( Value : in Element_Type; Deque : in Deque_Type ) return Deque_Type;
  function Top_Front ( Deque : in Deque_Type ) return Deque_Type;
  function Top_Rear ( Deque : in Deque_Type ) return Deque_Type;
  function Pop_Front ( Deque : in Deque_Type ) return Element_Type;
  function Pop_Rear ( Deque : in Deque_Type ) return Element_Type;
  procedure Print ( Deque : in Deque_Type );
end Deque_FD_2;
Functional Decomposition
Name/Parameter Tradeoffs

package Deque FD 3 is
  -- declarations for Element Type and Deque Type
  type Location Type is ( Front, Rear );
  procedure Push ( Value : in Element Type; Deque : in out Deque Type; Direction : in Location Type );
  procedure Pop ( Value : out Element Type; Deque : in out Deque Type; Direction : in Location Type );
  procedure Print ( Deque : in Deque Type );
end Deque FD 3;

Functional Decomposition
Side Effects (Operational)

package Deque FD 4 is
  -- declarations for Element Type and Deque Type
  type Location Type is ( Front, Rear );
  procedure Put In ( Direction : in Location Type );
  procedure Push ( Value : in Element Type; Deque : in out Deque Type );
  procedure Pop ( Value : out Element Type; Deque : in out Deque Type );
  procedure Print ( Deque : in Deque Type );
end Deque FD 4;

package Deque FD 5 is
  -- declarations for Element Type and Deque Type
  procedure Put In ( Front );
  procedure Put In ( Rear );
  -- same operations as in the previous example
end Deque FD 5;
Functional Decomposition
Side Effects (Global Data)

package Deque_FD is
  -- declarations for Element_Type and Deque_Type
  type Location_Type is ( Front, Rear );
  Location : Location_Type;
  -- same operations as in the previous example
end Deque_FD;

Deque Abstract Data Object
Visible Data Representation

package Deque_ADO is
  type Element_Type is new Natural;
  type Location_Type is ( Front, Rear );
  The_Deque : array ( 1 .. 100 ) of Element_Type;
  Top, Bottom : Integer range 0 .. The_Deque'Last - 1;
  procedure Push ( Value : in Element_Type; Into : in Location_Type );
  procedure Pop ( Value : out Element_Type; Out_of : in Location_Type );
  procedure Print;
end Deque_ADO;
Deque Abstract Data Object
Visible Data Representation

Analysis

• Reuse Potential:

• Abuse Potential:

• Change Analysis:

Deque Abstract Data Object
Hidden Data Representation

package Deque.ADO2 is

  type Element_Type is new Natural;

  procedure Push_Front ( Value : in Element_Type );
  procedure Push_Rear ( Value : in Element_Type );

  procedure Pop_Front ( Value : out Element_Type );
  procedure Pop_Rear ( Value : out Element_Type );

  procedure Print;

end Deque.ADO2;
Deque Abstract Data Object
Hidden Data Representation

Analysis

• Reuse Potential:

• Abuse Potential:

• Change Analysis:

Deque Abstract Data Type
Visible Type Implementation

package Deque ADT,1 is

Deque_Size : constant := 100;

type Element_Type is new Natural;
type Deque_Index_Type is range 1 .. Deque_Size;
type Location_Type is ( Front, Rear );

type The_Deque is array ( Deque_Index_Type ) of Element_Type;

type Deque_Type is

record

Top,
Bottom : Deque_Index_Type;
Empty : Boolean := true,
List : The_Deque;

end record;

procedure Push ( Value : in Element_Type; Onto : in out Deque_Type;
Direction : in Location_Type );

procedure Pop ( Value : out Element_Type; From : in out Deque_Type;
Direction : in Location_Type );

procedure Print ( Value : in Deque_Type );

end Deque_AD T, 1;
Deque Abstract Data Object
Visible Type Implementation

Analysis

- Reuse Potential:
- Abuse Potential:
- Change Analysis:

package Deque_ADT_A is
  type Element_Type is new Natural;
  type Location_Type is (Front, Rear);
  type Deque_Type (Deque_Size : Positive := 100) is private;
  -- Same operations as in the previous example.
  private
    subtype Deque_Max_Size is Positive range 1 .. 100;
    type The_Deque is array (Deque_Max_Size range <>) of Element_Type;
    type Deque_Type (Deque_Size : Positive := 100) is record
      Top,
      Bottom : Positive;
      Empty : Boolean := true;
      List : The_Deque (1 .. Deque_Size);
    end record;
end Deque_ADT_A;
Deque Abstract Data Object
Data Encapsulation: Array Implementation

Analysis
- **Reuse Potential:**

- **Abuse Potential:**

- **Change Analysis:**

Deque Abstract Data Type
Data Encapsulation: Linked List Implementation

```plaintext
package Deque ADT.L is
   -- Same operations and type declarations as in the previous example.
   private
   type Node;
   type Link; Type is access Node;
   type Deque_Type (Deque_Size : Positive := 100) is record
      Top,
      Bottom : Link; Type := null;
      end record;
   type Node is record
      Value : Element; Type;
      Previous,
      Next : Link; Type := null;
      end record;
end Deque ADT.L;
```
Deque Abstract Data Object
Data Encapsulation: Linked List Implementation

Analysis

- **Reuse Potential:**
- **Abuse Potential:**
- **Change Analysis:**

Deque Abstract Data Type
Data Encapsulation: Heterogeneous Elements

package Deque_ADT_H is

  type Natural_Type is new Natural;
  type Float_Type is new Float;

  type Element_Types is (Natural,Kind,Float,Kind);

  type Element_Type (Kind:Element_Types := Natural,Kind) is
  record
    case Kind is
      when Natural => Natural,Value : Natural,Type;
      when Float,Kind => Float,Value : Float,Type;
    end case;
  end record;

  type Location_Type is (Front,Rear);

  type Deque_Type (Deque_Size:Positive := 100) is private;

  -- Same operations as in the previous example.
  private

  -- Same type declarations as in the previous example.
end Deque_ADT_H;
Deque Abstract Data Object

Data Encapsulation: Heterogeneous Elements

Analysis

- **Reuse Potential:**

- **Abuse Potential:**

- **Change Analysis:**

Parameterized (Generic) ADT

Generic Deque: Array Implementation

```plaintext
generic
type Element, Type is private;
Default, Deque, Size : Positive := 100,

with procedure Print ( Value : Element, Type );
package Deque, GADT, A is
type Location, Type is ( Front, Rear );
type Deque, Type ( Default, Deque, Size ) is private;
-- Same operations as in the previous example.
private
-- Same as in section 5.1
end Deque, GADT, A;
```
Parameterized (Generic) ADT

Generic Deque: Array Implementation

Analysis

- **Reuse Potential:**
  
- **Abuse Potential:**
  
- **Change Analysis:**

Parameterized (Generic) ADT

Deque: Linked List Implementation

```haskell
generic
  -- Same generic formal parameters

package Deque.GADT.L is
  -- Same operations and declarations as in the previous example

private
  -- Same type declarations as example 5.2
end Deque.GADT.L;
```
Parameterized (Generic) ADT
Generic Deque: Hidden Implementation

Analysis

- Reuse Potential:

- Abuse Potential:

- Change Analysis:

Reusability Assessment
Understandability

- selecting the proper operation
- supplying the right actual subprogram parameter
- declaring a variable of a certain type
- specifying actual generic parameters
- modifying the package specification
- modifying the package body
Reusability Assessment

Summary of Interface Styles

- Package Format
  - functional decomposition with no state
  - functional decomposition with residual control
    abstract data object
  - abstract data type
  - parameterized (generic) ADT/ADO, etc.
- retain data and control state information
- tradeoff: Operations/parameters

Summary of Interface Styles

- State data can be
  - hidden in the package body
  - protected in a private section
  - exposed in the specification
- Data Encapsulation protects integrity of data.
- Data Encapsulation limits reusability.
- Private data is useful for documentation and modification.
- Hiding state and control data requires more effort to modify but makes for a cleaner interface.
**Composition**

**Deque -> Stack/Queue**

- Abstract Data Object ->
  - Abstract Data Object
- Abstract Data Type ->
  - Abstract Data Object
  - Abstract Data Type
- Generic Abstract Data Type ->
  - Abstract Data Object
  - Abstract Data Type
  - Generic Abstract Data Type

---

**Ada Reuse Mechanisms**

- with clause
- rename statement
- subtype declaration
- derived type declaration
Stack ADO from Deque ADO
Using Derived Types

with Deque.ADO.1;
package St.01 is
    package DQ renames Deque.ADO.1;
    type Element_Type is new DQ.Element_Type;
    procedure Push ( Value : in Element_Type );
    procedure Pop ( Value : out Element_Type );
    procedure Print renames DQ.Print;
end St.01;

package body St.01 is
    procedure Push ( Value : in Element_Type ) is
        begin
            DQ.Push ( DQ.Element_Type( Value ), Direction => DQ.Front );
        end Push;

    procedure Pop ( Value : out Element_Type ) is
        begin
            Pop ( Value, Direction => DQ.Front );
        end Pop;

    procedure Print is taken care of in the specification
end St.01;

Stack ADO from Deque ADT
Using Subtypes

with Deque.ADO.1;
package St.1 is
    package DQ renames Deque.ADO.1;
    subtype Element_Type is DQ.Element_Type;
    procedure Push ( Value : in Element_Type );
    procedure Pop ( Value : out Element_Type );
    procedure Print;
end St.1;

package body St.1 is
    Stack1 : DQ.Deque_Type; -- declare the object

    procedure Push ( Value : in Element_Type ) is
        begin
            DQ.Push ( Value, Stack1, Into => DQ.Front );
        end Push;

    procedure Pop ( Value : out Element_Type ) is
        begin
            DQ.Pop ( Value, Stack1, OutOf => DQ.Front );
        end Pop;

    procedure Print is
        begin
            DQ.Print( Stack1 );
        end Print;
end St.1;
Queue ADT from Deque ADT
Using Subtypes

with Deque FD I;
package QADTI,DADTI is

package DQ renames Deque FD I;
subtype Element Type is DQ Element Type;
subtype Queue Type is DQ Deque Type;

procedure Push ( Value : in Element Type;
              Deque : in out Queue Type ) renames DQ Push Front;

procedure Pop ( Value : out Element Type;
              Deque : in out Queue Type ) renames DQ Pop Rear;

procedure Print ( Value : in Stack Type ) renames DQ Print;
end QADTI,DADTI;

Stack ADO from Generic Deque ADT

package SADOI,DGADTI is

subtype Element Type is Integer;

procedure Push ( Value : in Element Type );
procedure Pop ( Value : out Element Type );
procedure Print;

end SADOI,DGADTI;

with Deque,GADTI A;
with Text IO, use Text IO;
package body SADOI,DGADTI is

package Int IO is new Integer IO (Integer);
procedure Print ( N : in Integer);
package DQ is new Deque,GADTI ( Integer, 100, Print );

Stack1 : DQ Deque Type; -- Declare the object.

procedure Print ( N : in Integer ) is
begin
    Put ( N );
end Print;

-- See section 8.3.1 for implementation of Push, Pop and Print.
end SADOI,DGADTI;
Stack Generic ADT from Generic Deque ADT

with Deque.GADTI; generics
  type Stack_Type is private;
  type Stack_Type is private;
end Stack_Type;

package SGADTI is
  type Stack_Type is private;
  type Stack_Type is private;
end SGADTI;

procedure Push (Value : in out Stack_Type; From : in out Stack_Type);
procedure Push (Value : in out Stack_Type; From : in out Stack_Type);

procedure Pop (Value : in out Stack_Type);
procedure Pop (Value : in out Stack_Type);

procedure Print (Value : in Stack_Type);
procedure Print (Value : in Stack_Type);

end SGADTI;

package body SGADTI is
  ....

end SGADTI;
Software Reuse Rules of Thumb
The Questions

1. What software *should* be made reusable?

2. *How* is software made reusable?

Software Reuse Rules of Thumb
The Answers

1. To identify software for reuse, factor out commonality.

2. To develop reusable software, separate context from concept and content.
Factoring Out Commonality

The Questions

1. What software is common among most applications?

2. What software is common within a specific application domain?

Domain Analysis

Biggerstaff’s Guidelines

A good domain for reuse is one that

1. encompasses well understood abstractions,

2. has only a few data types,

3. depends on an underlying technology that is stable, and

4. has standards within the problem domain.
Software Reuse Maxim

Before software can be

reusable,

it needs to be

useful.

Separating Context
Sort Example

1. **Data:** (e.g., payroll records, student grades)

2. **Data Structure:** (e.g., linked list, an array, or in a file.

3. **Variations:** (e.g., ascending or descending order)

4. **Hardware Dependencies:**

5. **Operating System/Data Base Dependencies:**

6. **User Interface:**
Software Reuse Maxim

Before software can be reusable,
it needs to be useable.

Software Reuse Rules of Thumb
Corollaries

1. Separate the interface from the implementation.

2. Isolate dependencies through virtual interfaces.

Separate Concept from Content
Reuse Checklist

Strategy

Domain Analysis:
factoring out commonality and factoring in generality.

Design for Reuse:
separating context from content through modularization and parameterization.

Domain Analysis

What software should be made reusable?

- What is common among software applications?
  - Common implementation language?
  - Written for the same operating system?
  - Uses the same data–base system?
  - Has the same user interface?
  - Works on the same hardware platform?
  - Has the same functionality?
Domain Analysis Checklist

- What is common between current versions and future applications?
- How many future applications will be similar to current implementations?
- What kind of changes in requirements can be envisioned for future versions of existing applications?

Domain Analysis

Checklist

- What is common among versions of a certain application?
- Common modularity? Are some of each system's modules the same, or similar?
- Written for the same operating system?
- Uses the same data - base system?
- Has the same user interface?
- Works on the same hardware platform?
- Has the same functionality?
Domain Analysis

Checklist

- What is common between current versions and future applications?
  - Written for the new operating system?
  - Uses a new database system?
  - Has a new user interface?
  - Works on a different hardware platform?

- Can a business case be made to justify the cost of creating a baseline?
- Can a business case be made to justify the cost of creating an application generator?
- Can these questions be answered by in-house experts?
- Is management willing to support the development, documentation, maintenance and training effort to support reuse?
Design for Reuse
(How to make software Reusable?)

• What is the best way to modularize the application for reuse?
  - Can operations be grouped that work on the same kind of data (abstract data type)?

• Can global data be eliminated or encapsulated in modules along with the operations that manipulate it (data encapsulation)?

• Can implementations be separated from interfaces (program families)?

Design for Reuse Checklist

• Can algorithms be generalized to work on different
  - hardware,
  - operating systems,
  - I/O devices,
  - user interfaces, or
  - data structures/data bases?
Design for Reuse
Checklist

- Can virtual interfaces be defined to separate
  - hardware,
  - operating system,
  - I/O,
  - user interface, or
  - data structure/data - base dependencies?

Design for Reuse
Checklist

- What documentation is necessary to help the user
  - reuse,
  - locate,
  - understand, or
  - modify the software?
Design for Reuse
Checklist

- Can the domain of applicability of a function or module be increased through parameterization?

- Can tests be built in to assure parameters are correct on invocation?

- Can tests be built in to assure parameters are correct on instantiation?

Software Reuse Rules of Thumb
The Answers

1. To identify software for reuse, factor out commonality.

2. To develop reusable software, separate context from concept and content.
General Reuse Guidelines
Ed Berard

The following *increase* reusability:

- Following standards
- Management encouragement
- Code without language or implementation tricks
- Portable code
- Reliable code
- Functionally cohesive and loosely coupled modules
- Well defined interfaces
- Generality and Robustness
- Conceptual Integrity

Ada Reuse Guidelines
Ed Berard

Reusability is *increased* when using

- meaningful mnemonics
- attributes
- named parameters
- fully qualified names
- precise, concise comments
- subunits and separate compilation
- packages
- generics
- isolated machine dependencies
- isolated application specific dependencies
Ada Reuse Guidelines
Ed Berard

Reusability is *decreased* when using

- literal constants
- use clause
- default values for:
  - discriminants
  - record field values
  - formal parameters
- optional language features:
  - pragmas
  - unchecked – deallocation
  - unchecked – conversion

Ada Reuse Guidelines
Ed Berard

Reusability is *decreased* when using

- anonymous types
- pre-defined and implementation-defined types
- attention to underlying implementation
- restrictive modules
- assumptions about garbage collection