Module Guide for Projectile

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1 Introduction

Decomposing a system into modules is a commonly accepted approach to developing software. A module is a work assignment for a programmer or programming team (Parnas et al., 1984). In the best practices for scientific computing (SC), Wilson et al. (2013) advise a modular design, but are silent on the criteria to use to decompose the software into modules. We advocate a decomposition based on the principle of information hiding (Parnas, 1972). This principle supports design for change, because the "secrets" that each module hides represent likely future changes. Design for change is valuable in SC, where modifications are frequent, especially during initial development as the solution space is explored.

Our design follows the rules layed out by Parnas et al. (1984), as follows:

- System details that are likely to change independently should be the secrets of separate modules.
- Each data structure is used in only one module.
- Any other program that requires information stored in a module's data structures must obtain it by calling access programs belonging to that module.

After completing the first stage of the design, the Software Requirements Specification (SRS), the Module Guide (MG) is developed (Parnas et al., 1984). The MG specifies the modular structure of the system and is intended to allow both designers and maintainers to easily identify the parts of the software. The potential readers of this document are as follows:

- New project members: This document can be a guide for a new project member to easily understand the overall structure and quickly find the relevant modules they are searching for.
- Maintainers: The hierarchical structure of the module guide improves the maintainers' understanding when they need to make changes to the system. It is important for a maintainer to update the relevant sections of the document after changes have been made.
- Designers: Once the module guide has been written, it can be used to check for consistency, feasibility and flexibility. Designers can verify the system in various ways, such as consistency among modules, feasibility of the decomposition, and flexibility of the design.

The rest of the document is organized as follows. Section 2 lists the anticipated and unlikely changes of the software requirements. Section 3 summarizes the module decomposition that was constructed according to the likely changes. Section 4 specifies the connections between the software requirements and the modules. Section 5 gives a detailed description of the modules. Section 6 includes two traceability matrices. One checks the completeness

of the design against the requirements provided in the SRS. The other shows the relation between anticipated changes and the modules. Section 7 describes the use relation between modules.

2 Anticipated and Unlikely Changes

This section lists possible changes to the system. According to the likeliness of the change, the possible changes are classified into two categories. Anticipated changes are listed in Section 2.1, and unlikely changes are listed in Section 2.2.

2.1 Anticipated Changes

Anticipated changes are the source of the information that is to be hidden inside the modules. Ideally, changing one of the anticipated changes will only require changing the one module that hides the associated decision. The approach adapted here is called design for change. Anticipated changes are numbered by **AC** followed by a number.

AC1: The specific hardware on which the software is running.

AC2: The format of the initial input data.

AC3: The format of the input parameters.

AC4: The constraints on the input parameters.

AC5: The format of the final output data.

AC6: The constraints on the output results.

AC7: How the overall control of the calculations is orchestrated.

AC8: The implementation for the sequence (array) data structure.

2.2 Unlikely Changes

The module design should be as general as possible. However, a general system is more complex. Sometimes this complexity is not necessary. Fixing some design decisions at the system architecture stage can simplify the software design. If these decision should later need to be changed, then many parts of the design will potentially need to be modified. Hence, it is not intended that these decisions will be changed. As an example, the ODEs for the temperature and the energy equations are assumed to follow the structure given in the SRS; that is, even if they need to be modified, the modifications should be possible by changing how the input parameters are used in the definition. If new parameters are needed, this will mean a change to both the input parameters module, the calculation module and the output module. Unlikely changes are numbered by **UC** followed by a number.

UC1: Input/Output devices (Input: File and/or Keyboard, Output: File, Memory, and/or Screen).

UC2: There will always be a source of input data external to the software.

UC3: Output data are displayed to the output device.

UC4: The goal of the system is to determine if the projectile hits the target.

3 Module Hierarchy

This section provides an overview of the module design. Modules are summarized in a hierarchy decomposed by secrets in Table 1. The modules listed below, which are leaves in the hierarchy tree, are the modules that will actually be implemented. Modules are numbered by **M** followed by a number.

M1: Hardware-Hiding Module

M2: Input Parameters Module

M3: Output Format Module

M4: Control Module

M5: Specification Parameters Module

M6: Sequence Data Structure Module

Note that M1 is a commonly used module and is already implemented by the operating system. It will not be reimplemented. Similarly, M6 and M**??** are already available in Matlab and will not be reimplemented.

Level 1	**Level 2**
Hardware-Hiding	
Behaviour-Hiding	Input Parameters Output Format Control Module Specification Parameters Module
Software Decision	Sequence Data Structure

Table 1: Module Hierarchy

4 Connection Between Requirements and Design

The design of the system is intended to satisfy the requirements developed in the SRS. In this stage, the system is decomposed into modules. The connection between requirements and modules is listed in Table 2.

5 Module Decomposition

Modules are decomposed according to the principle of "information hiding" proposed by Parnas et al. (1984). The *Secrets* field in a module decomposition is a brief statement of the design decision hidden by the module. The *Services* field specifies *what* the module will do without documenting *how* to do it. For each module, a suggestion for the implementing software is given under the *Implemented By* title. If the entry is *OS*, this means that the module is provided by the operating system or by standard programming language libraries. If the entry is *Matlab*, this means that the module is provided by Matlab. *SWHS* means the module will be implemented by the SWHS software. Only the leaf modules in the hierarchy have to be implemented. If a dash (–) is shown, this means that the module is not a leaf and will not have to be implemented. Whether or not this module is implemented depends on the programming language selected.

5.1 Hardware Hiding Modules (M1)

Secrets: The data structure and algorithm used to implement the virtual hardware.

Services: Serves as a virtual hardware used by the rest of the system. This module provides the interface between the hardware and the software. So, the system can use it to display outputs or to accept inputs.

Implemented By: OS

5.2 Behaviour-Hiding Module

Secrets: The contents of the required behaviours.

Services: Includes programs that provide externally visible behaviour of the system as specified in the software requirements specification (SRS) documents. This module serves as a communication layer between the hardware-hiding module and the software decision module. The programs in this module will need to change if there are changes in the SRS.

Implemented By: –

5.2.1 Input Parameters Module (M2)

Secrets: The data structure for input parameters, how the values are input and how the values are verified. The load and verify secrets are isolated to their own access programs (like submodules). This, combined with the fact that all of the services are invoked together, suggests that the one module one secret rule can be relaxed here.

Services: Gets input from user (including material properties, processing conditions, and numerical parameters), stores input and verifies that the input parameters comply with physical and software constraints. Throws an error if a parameter violates a physical constraint. Throws a warning if a parameter violates a software constraint. Stored parameters can be read individually, but write access is only to redefine the entire set of inputs.

Implemented By: Projectile

5.2.2 Output Format Module (M3)

Secrets: The format and structure of the output data.

Services: Outputs the results of the calculations, including the input parameters, temperatures, energies, and times when melting starts and stops.

Implemented By: Projectile

5.2.3 Control Module (M4)

Secrets: The algorithm for coordinating the running of the program.

Services: Provides the main program.

Implemented By: Projectile

5.2.4 Specification Parameters Module (M5)

Secrets: The values of the specification parameters (such as bounds for software constraints on input variables).

Services: Read access for the specification parameters.

Implemented By: Projectile

5.3 Software Decision Module

Secrets: The design decision based on mathematical theorems, physical facts, or programming considerations. The secrets of this module are *not* described in the SRS.

Services: Includes data structure and algorithms used in the system that do not provide direct interaction with the user.

Implemented By: –

5.3.1 Sequence Data Structure Module (M6)

Secrets: The data structure for a sequence data type.

Services: Provides array manipulation, including building an array, accessing a specific entry, slicing an array, etc.

Implemented By: Matlab

6 Traceability Matrix

This section shows two traceability matrices: between the modules and the requirements and between the modules and the anticipated changes. Three of the anticipated changes (AC2, AC3, AC4) related to the input parameters map to the same module (M2). The reason for this is that the services of this module will never need to be provided separately. Input will be provided to the system, stored and verified at the beginning of any simulation. From that point on, the only access needed to the input parameters is read access.

[We should also document the mapping between these "abstract" modules and the Matlab files. —SS]

Req.	Modules
R1	M1, M2, M4
R2	M2
R3	M2, M5
R4	M3, M4
R5	M3, M4, M6
R6	M3, M4, M6
R7	M3, M4, M6
R8	M3, M4, M6
R9	M3, M4
R10	M3, M4

Table 2: Trace Between Requirements and Modules

AC	Modules
AC1	M1
AC2	M2
AC3	M2
AC4	M2
AC5	M3
AC7	M4
AC8	M6
AC??	M??

Table 3: Trace Between Anticipated Changes and Modules

7 Use Hierarchy Between Modules

In this section, the uses hierarchy between modules is provided. Parnas (1978) said of two programs A and B that A *uses* B if correct execution of B may be necessary for A to complete the task described in its specification. That is, A *uses* B if there exist situations in which the correct functioning of A depends upon the availability of a correct implementation of B. Figure **??** illustrates the use relation between the modules. It can be seen that the graph is a directed acyclic graph (DAG). Each level of the hierarchy offers a testable and usable subset of the system, and modules in the higher level of the hierarchy are essentially simpler because they use modules from the lower levels.

References

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