

# Module Guide for VDisp

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# 1 Revision History

| Date         | Version | Notes                |
|--------------|---------|----------------------|
| May 10, 2022 | 1.0     | Initial Module Guide |

## 2 Reference Material

This section records information for easy reference.

### 2.1 Abbreviations and Acronyms

| symbol | description                               |
|--------|---|
| AC     | Anticipated Change                        |
| DAG    | Directed Acyclic Graph                    |
| M      | Module                                    |
| MG     | Module Guide                              |
| OS     | Operating System                          |
| R      | Requirement                               |
| SC     | Scientific Computing                      |
| SRS    | Software Requirements Specification       |
| VDisp  | Visual Display — Soil Settlement Analysis |
| UC     | Unlikely Change                           |

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### 3 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 (?). We advocate a decomposition based on the principle of information hiding (?). 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 ?, as follows:

- System details that are likely to change independently should be the secrets of separate modules.
- Each data structure is implemented 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 (?). 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 4 lists the anticipated and unlikely changes of the software requirements. Section 5 summarizes the module decomposition that was constructed according to the likely changes. Section 6 specifies the connections between the software requirements and the modules. Section 7 gives a detailed description of the modules. Section 8 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 9 describes the use relation between modules.

## 4 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 4.1, and unlikely changes are listed in Section 4.2.

### 4.1 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.

**AC1:** Unit conversions

**AC2:** Solve multiple problems at once to compare results

**AC3:** Solve using multiple models to compare results

**AC4:** User specified file formats

**AC5:** Extend to multiple dimensions

**AC6:** Toggle assumption that each soil layer is isotropic

**AC7:** Toggle assumption that each soil layer is homogenous

**AC8:** Toggle the assumption of a semi-infinite half-space

**AC9:** Add graphical user interface

**AC10:** Use different Boussineq equations

**AC11:** Error approximation

**AC12:** User interaction (update values during simulation)

**AC13:** Time period for Schmertann model rather than single point in time

### 4.2 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.

**UC1:** Add different coordinate systems

**UC2:** Toggle uniform pressure distribution assumption

**UC3:** Incorporation of finite element model

## 5 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.

**M1:** Hardware-Hiding Module

**M2:** Input Parameters Module

**M3:** Output Format Module

**M4:** Equations Module

**M5:** Control Module

**M6:** Display Module

**M7:** Plotting Module

| Level 1                  | Level 2                 |
|--------------------------|-------------------------|
| Hardware-Hiding Module   |                         |
|                          | Input Parameters Module |
|                          | Output Format Module    |
| Behaviour-Hiding Module  | Equation Module         |
|                          | Control Module          |
|                          | Display Module          |
| Software-Decision Module | Plotting Module         |

Table 1: Module Hierarchy

## 6 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.

The intention of this section is to document decisions that are made “between” the requirements and the design. To satisfy some requirements, design decisions need to be made. Rather than make these decisions implicit, they are explicitly recorded here. For instance, if a program has security requirements, a specific design decision may be made to satisfy those requirements with a password. In scientific examples, the choice of algorithm could potentially go here, if that is a decision that is exposed by the interface.

## 7 Module Decomposition

Modules are decomposed according to the principle of “information hiding” proposed by ?. 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 *Julia*, this means the module is provided by Julia. *VDisp* means the module will be implemented by the *VDisp* 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.

### 7.1 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

### 7.2 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:** –

#### 7.2.1 Input Parameters Module (M2)

**Secrets:** The format and structure of the input data.

**Services:** Converts the input data into the data structure used by the Display, Control, and Output Format modules.

**Implemented By:** VDisp



### 7.2.2 Output Format Module (M3)

**Secrets:** The format and structure of the output data.

**Services:** Outputs the result of the calculations, including model used for calculations, effective stress, and total displacement.

**Implemented By:** VDisp

### 7.2.3 Equations Module (M4)

**Secrets:** The equations for solving for effective stress, consolidation swell, and displacement using the input parameters.

**Services:** Defines the equations using the parameters in the input parameters module.

**Implemented By:** VDisp

### 7.2.4 Control Module (M5)

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

**Services:** Provides the main program.

**Implemented By:** VDisp

### 7.2.5 Display Module (M6)

**Secrets:** The methods by which it displays input data and output data, along with any other info to the screen.

**Services:** Displays the program.

**Implemented By:** VDisp

## 7.3 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:** –

### 7.3.1 Plotting Module (M7)

**Secrets:** The methods for plotting given data.

**Services:** Plots the given data.

**Implemented By:** Julia

## 8 Traceability Matrix

This section shows two traceability matrices: between the modules and the requirements and between the modules and the anticipated changes.

| Req. | Modules                    |
|------|----------------------------|
| R1   | M1, M2, M??, M5            |
| R2   | M2, M??                    |
| R3   | M??                        |
| R4   | M3, M5                     |
| R5   | M3, M??, M5, M??, M??, M?? |
| R6   | M3, M??, M5, M??, M??, M?? |
| R7   | M3, M??, M5, M??, M??      |
| R8   | M3, M??, M5, M??, M??      |
| R9   | M??                        |
| R10  | M3, M??, M5                |
| R11  | M3, M??, M??, M5           |

Table 2: Trace Between Requirements and Modules

| AC   | Modules |
|------|---------|
| AC?? | M1      |
| AC?? | M2      |
| AC?? | M??     |
| AC?? | M??     |
| AC?? | M3      |
| AC?? | M??     |
| AC?? | M??     |
| AC?? | M??     |
| AC?? | M5      |
| AC?? | M??     |
| AC?? | M??     |
| AC?? | M??     |

Table 3: Trace Between Anticipated Changes and Modules

## 9 Use Hierarchy Between Modules

In this section, the uses hierarchy between modules is provided. ? 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 1 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.

Figure 1: Use hierarchy among modules