Title: DC-OMS Components and Coupling

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Abstract

The report describes the results of the Delft Cluster project *DC-OMS Components and Coupling*, that is part of the baseproject ‘DC-OMS’ (Delft Cluster Open Modelling Systems).

The *DC-OMS Components and Coupling* project contains three sub-projects. For every sub-project, the present report describes it results in a general way. Where convenient, the report refers to the content of additional reports that provide the details that one might be interested in.

The activities and results of the three sub-projects are:

1. **Data Exchange on Element Sets in the Generic Framework**
   This sub-project has been performed in by Delft Hydraulics, in co-operation with the Generic Framework consortium; its aim can be defined as:
   - provide the Generic Frame Work with an additional interface for exchanging data that is available on so called ‘data fields’.
   - improve the performance by replacing the current data exchange (which is done per value per item) by the ‘field based’ data exchange.

2. **MSettle/Diana Coupling**
   This sub-project, executed by TNO-Construction and GeoDelft, has served as a pilot for the DC-OMS-Architecture project. It focused on
   - realising a MSettle/Diana coupling
   - analysis of the data exchange between MSettle and Diana
   Indeed a research version of coupling MSettle/Diana has been realized. However, for full operational usages, quite some improvements are required.

3. **Development of a Probabilistic Component**
   A few years ago, the Dutch Rijkswaterstaat (Bouwdienst) and TNO-Construction developed a first implementation for probabilistic analysis, based on DIANA. This project, a co-operation between TNO-Construction and GeoDelft, has restructured this first ad hoc implementation in such a way that this probabilistic component easily can be reused, e.g. in GeoDelft’s M-Series.
Executive Summary

The project ‘DC-OMS Components and Coupling’ is one of the projects in the Delft Cluster baseproject ‘DC-OMS’ (Delft Cluster Open Modelling Systems).

The project has been subdivided into three sub-projects:

4. **Data Exchange on Element Sets in the Generic Framework**
   This sub-project, a co-operation of Delft Hydraulics and the Generic Framework consortium has: provided the Generic Frame Work with an efficient and easy to use way for exchanging computed data between software components that run in the Generic Framework.

5. **MSettle/Diana Coupling**
   This sub-project has realised a research version of coupling GeoDelft’s MSettle and TNO-Construction’s DIANA.

6. **Development of a Probabilistic Component**
   A few years ago, the Dutch Rijkswaterstaat (Bouwdienst) and TNO-Construction developed a first implementation for probabilistic analysis, based on DIANA. This project has restructured this implementation in such a way that this probabilistic component easily can be reused, e.g. in GeoDelft’s M-Series.
Applicability for the sector

Software systems are becoming increasingly important for knowledge transfer to the sector; this project contributes to the availability of reusable software components that can be easily integrated into existing software systems.

The baseproject *Delft Cluster Open Modelling Systems* (DC-OMS) facilitates the integration of software components amongst the Delft Cluster partners and the sector.

The DC-OMS Components and Coupling project has:
- provided efficient data exchange between components
- generated knowledge and tools to integrate existing components
- produced a reusable software component for statistical analysis.
Societal Relevance of the research

Society increasingly requires an integrated approach to water management.

The baseproject *Delft Cluster Open Modelling Systems* (DC-OMS) facilitates the integration of software components amongst the Delft Cluster partners and the sector.

The DC-OMS Components and Coupling project has:
- provided efficient data exchange between components
- generated knowledge and tools to integrate existing components
- produced a reusable software component for statistical analysis.
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1 Introduction

The report describes the progress and the results of the Delft Cluster project DC-OMS Components and Coupling. This project is part of the baseproject ‘DC-OMS’ (Delft Cluster Open Modelling Systems).

The DC-OMS Components and Coupling project contains three sub-projects. For every sub-project, the report describes its results in a general way. Whenever necessary, references are made to additional reports that provide details on the subject (see for these reports next page - Table 1).

The activities and results of each of the three sub-projects are described in a separate Chapter:

1. Data Field Exchange in the Generic Framework (Chapter 2)
   This sub-project has been performed in by Delft Hydraulics, in co-operation with the Generic Framework consortium, and aimed at:
   • providing the Generic Framework with an additional interface for exchanging data that is available on so called ‘element sets’ whole ‘data fields’;
   • improving the GF performance by replacing the current data exchange by the ‘field based’ data exchange.

2. MSettle/Diana Coupling (Chapter 3)
   This sub-project, a co-operation between GeoDelft and TNO-Construction, focused on:
   • realising a first version of a MSettle/Diana coupling for 1D/2D geotechnical computations;
   • analysis of the data exchange between MSettle and Diana (which served as a pilot for the DC-OMS-Architecture project).

3. Development of a Probabilistic Component (Chapter 4)
   In this sub-project, executed by TNO-Construction in co-operation with Rijkswaterstaat, HSL-Zuid and GeoDelft, a Probabilistic Component has been developed that can be used for system failure analyses, for example to determine structural reliability. During the sub-project execution, reports have been produced on (a.o.):
   • Specification and design of the probabilistic computational core module, the output module for the probabilistic core, and the communication between these modules and DIANA,
   • Design of graphical user interface.
<table>
<thead>
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<th>Report</th>
<th>Author(s)</th>
<th>Company</th>
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<td><em>Data Field Exchange in the Generic Framework</em></td>
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<td>Technical Design GF Data Fields, June 2003</td>
<td>S. Hummel</td>
<td>WL</td>
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<tr>
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<td>WL</td>
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<td>Definitiestudie (Dutch), August 2001</td>
<td>M. Visschedijk, M. ’t Hart</td>
<td>GeoDelft</td>
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<td>Functional Design, December 2001</td>
<td>S. Branchett</td>
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<td>DC-OMS Architecture, Pilots, February 2002</td>
<td>S. Hummel, B.S.T. The</td>
<td>WL</td>
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<td>Specifications, report 2002-NM-R001</td>
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<td>S. Branchett</td>
<td>TNO Construction</td>
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<td>Communication layer, report 2002-NM-R006</td>
<td>S. Branchett</td>
<td>TNO Construction</td>
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<td>Storage Requirements, report 2002-NM-R007</td>
<td>S. Branchett</td>
<td>TNO Construction</td>
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<td>GUI Design, report 2002-NM-R008</td>
<td>A. van der Geer</td>
<td>TNO Construction</td>
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<td>Core Design DARS (Directional Adaptive Response Surface Sampling), report 2002-NM-R017</td>
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<td>Output Design, report 2002-NM-R018</td>
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*Table 1, Project report overview*
2 Data Exchange on Element Sets in the Generic Framework

2.1 Introduction

To facilitate the use of the Generic Framework (see refs. Generic Framework), the GF has been extended with the so called AutoConnect module, that generates connections between models that provide and accept quantities on many locations (for instance on all grid points). When exchanging data between these models, all values will be exchange separately, by means of these generated connections. However, often the models provide and/or accept their quantities in arrays that contain the values on all locations (e.g. grid points). Therefore it is preferable that these kinds of quantities are exchanged on whole 'data fields' instead of on separate locations.

GF is a third party in Delft Cluster’s base project Open Modelling Systems’ (DC-OMS). The project Components and coupling project originally contained activity 'Time step based model iteration'. Due to the aspects mentioned in the previous paragraph, the content of this activity have been changed to the exchange of whole data fields.

2.2 Purpose

Figure 1 (see next page) pictures the purpose of the project. The right side of the figure shows the original Generic Framework approach. Every model is ‘wrapped’, and this wrapper provides all the model’s locations, as well as the quantities that are available and/or required on these locations, to the GF ‘case’ (the composition of models). As indicated in the previous section, the case contains the connections (the so called exchange items) between the location/quantity combinations of the two models (the GF terminology for location/quantity is ModelComponent/ModelAttribute, see picture).

The main purpose of the project is, to replace this way of communication by one that directly accesses the quantity arrays as provided/required by the model wrappers. This is shown in the left side of Figure 1.

The main effort has been put in ‘reconstructing’ the many individual connections back to ‘field to field’ connections. Once this was achieved, the actual data exchange itself was rather trivial.

A second, more or less derived purpose was to offer a model wrapper a simple interface to:

• define its data fields and the quantities provided/required on a field
• put and/or get values on these fields.

This has been achieved by using full string identification for data fields and for the locations on these data fields, as well as for the quantities that are exchanged. The developed Data Fields module translates this identification into the specific involved GF classes and objects. The interface for exchanging data in GF has been reduced to the functions that are listed in Table 2 (the function names have been adjusted in accordance to the terminology used in HarmonIT, see ref. HarmonIT).

Details of these functions, as well as the detailed design of the Data Field module, can be found in ref. Technical Design GF Data Fields.
2.3 Results

Due to quite some delay in finalising version 1.0 of the Generic Framework (now foreseen at September 2003), the Data Fields module has not been formally tested yet. The module has been fully implemented, and has been tested for the combination of two models.

![Diagram showing field-based data exchange in the Generic Framework](image)

**Figure 1, Field based data exchange in the Generic Framework**

<table>
<thead>
<tr>
<th>Function</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>DefineElementSet</td>
<td>Define element set on which quantities can be exchanged</td>
</tr>
<tr>
<td>DefineQuantity</td>
<td>Define a quantity that will be exchanged on an element set</td>
</tr>
<tr>
<td>PutDataField</td>
<td>Put data field values for an certain time stamp</td>
</tr>
<tr>
<td>GetDataField</td>
<td>Get data field values for an certain time stamp, and get a mask array on which elements if the data field (= element set) values were received indeed.</td>
</tr>
</tbody>
</table>

**Table 2, Generic Framework Data Fields interface**
3 MSettle/DIANA coupling

3.1 Introduction

The MSettle/DIANA coupling is the effectuation of the task ‘Geomechanische EEM-modellen’ (Geomechanic Finite Element Models), as defined in the project plan for the present project (see ref. DC-OMS Componenten en Koppelingen, Projectplan).

This Chapter described the results of the project, and refers to the various produced reports for details (see Chapter 1 for a description of these reports).

3.2 Purpose

Figure 2 shows the both the purpose and the achieved result of the MSettle/DIANA coupling. A coupling has been realized between MSettle and DIANA.

The user defines a model in MSettle, extends the model with additional information that is required by a 2D DIANA computation (1st and 2nd screen in Figure 2), and invokes ‘Run DIANA’. The MSettle model is exported to file that is read by DIANA (3rd screen), after which DIANA computes the required results (4th screen). The DIANA results are exported to file again, and are read in and presented by MSettle. (The 3rd and 4th screen are not shown to the user - the results are shown in MSettle; these screens just illustrate the process flow.)

Figure 2, MSettle/DIANA coupling
To determine the actions to be taken for this coupling, a definition study has been performed (See Koppeling MS\textit{Settle-Diana}, Definitiestudie for details). The definition study describes:

- The assumptions that have been made (and/or have to be made) to realise the MS\textit{Settle}/Diana coupling in a limited time;
- The various quantities that have to be exchanged (and if applicable, their location on the schematisation);
- The adjustments to be made to the existing components (see next Sections).

### 3.3 Adjustments to MS\textit{Settle} and DIANA

The adjustments to MS\textit{Settle} and DIANA can be pictured by looking at the process flow (see Figure 3), and can be summarised as follows:

**Figure 3, Process flow MS\textit{Settle}/DIANA**

1. **Input**
   - MS\textit{Settle} has been extended with information that is required by a 2D DIANA computation, like an option to enable the DIANA computation, and the generation of a mesh from the MS\textit{Settle} 2D Geometry schematisation.

2. **Mesh data**
   - DIANA transforms the mesh generated by MS\textit{Settle} into a mesh that can be read by DIANA.
3. **FEM-Data**

   DIANA translates the computation information into a so called *control file* for, and the various model characteristics into a DIANA model.

4. **FEM-results computation**

   MSettle invokes the DIANA computation, DIANA performs the computation,

5. **Required results**

   During and after computation, DIANA adjusts its internal results into a representation that is required by MSettle.

6. **Output**

   The adjust required results are read and visualised by MSettle.

### 3.4 Results

To test the coupled models, a few benchmark tests have been performed. These benchmarks are part of the *Verification report MSettle* (see reference). They now have been executed with a 2D DIANA computation instead of the original 1D MSettle computation.

The performed benchmark tests are listed in Table 3 (see ref. *Verification report MSettle* for details; DK stands for the Diana Coupling version).

<table>
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<th>Benchmark ID</th>
<th>Purpose</th>
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</thead>
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<td>bm3_5a_DK</td>
<td>Settlement (Koppejan) without submerging, a</td>
</tr>
<tr>
<td>bm3_5b_DK</td>
<td>Settlement (Koppejan) without submerging, b</td>
</tr>
<tr>
<td>bm3_6_DK</td>
<td>Final stresses using submerging of soil</td>
</tr>
<tr>
<td>demo-1_DK</td>
<td>Example number 1, Heightening of an embankment (Koppejan)</td>
</tr>
<tr>
<td>demo-4_DK</td>
<td>Example number 4, Soil improvement (embankment)</td>
</tr>
<tr>
<td>demo-5_DK</td>
<td>Example number 5, Effect of load steps</td>
</tr>
<tr>
<td>demo-6_DK</td>
<td>Example number 6, Heightening of an embankment (Isotache)</td>
</tr>
<tr>
<td>tutorial_DK</td>
<td>User Manual’s Tutorial</td>
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</tbody>
</table>

*Table 3, Benchmark tests MSettle/DIANA coupling*

Most tests were judged to be acceptable or good, but is has become clear that there are quite a few restrictions to this first version, e.g.:

- There may be only one non-uniform load
- For some parameters the distinction between wet and dry soil has not been made yet.

So additional work has to be done to realise an operational version of the MSettle/DIANA coupling.
4 Probabilistic component for DIANA

4.1 Introduction

A few years ago, the Dutch Rijkswaterstaat (Bouwdienst) and TNO-Construction developed a first implementation for probabilistic analysis, based on Diana. The present project has restructured this first ad hoc implementation in such a way that this probabilistic component easily can be reused, e.g. in GeoDelft’s M-Series.

The restructuring has been performed by TNO-Construction, in co-operation with GeoDelft.

4.2 Specification

As first step, a Specification Report has been written, clearly indication the purpose of the project, i.e. the functionality of the Probabilistic Component and the way it should be structured to in order to be isolated and therefore reusable.

Figure 4 (seen next page) shows the main parts of the component. Details can be found in the Specification Report (see ref. in Table 1, Chapter 1).

4.3 Approach

Given the specification, the project has been carried out in three stages, each leading to reports (see Table 1 in Chapter 1, ‘Introduction’, for produced reports).

Stage 1:
• A graphical user interface (GUI) was designed and developed to allow the user to steer a Directional Sampling (DS) probabilistic calculations using the linear static application in DIANA as the calculation engine.
• A probabilistic calculation application was designed and developed. The DS method and communication with DIANA has been implemented.

Stage 2:
• Extension of the GUI, to allow the user:
  • to steer Directional Adaptive Response Surface Sampling (DARS) probabilistic calculations using the linear static application in DIANA as the calculation engine
  • to indicate correlations between stochastic parameters
  • the user to select additional stochastic distribution types

Stage 3:
• The graphical user interface (GUI) has been extended, to:
  • allow the user to specify probabilistic calculations on problems with an EULER analysis type
  • allow the user to specify probabilistic calculations on problems with a NONLIN analysis type
  • improve user friendliness
• Further development of the probabilistic calculation application:
  • the DARS method has been designed and implemented
  • dealing with correlations between stochastic parameters has been designed and implemented (but not fully tested)
  • additional stochastic distribution types have been added
  • perform probabilistic calculations on problems with an EULER analysis type
• perform probabilistic calculations on problems with a NONLIN analysis type
• a very limited restart option has been implemented

In 2003, the project has been continued in a 4th stage:
• The graphical user interface (GUI) has been extended, to:
  • allow the user to specify probabilistic calculations on problems with a PHASED analysis type
• Further development of the probabilistic calculation application:
  • the FORM method has been designed and implemented
  • perform probabilistic calculations on problems with a PHASED analysis type

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**Figure 4, Structure of the Probabilistic Components**
4.4 Results

So far the following types of tests have been successfully performed:

- DS calculation for linear static, nonlinear, Euler and PHASED structural analyses
- DARS calculation for linear static, nonlinear and Euler structural analyses
- FORM calculation for Euler structural analyses

Unit tests were also performed for the use of correlation and for the use of reinforcements in structural analyses.
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General Appendix: Delft Cluster Research Programme Information

This publication is a result of the Delft Cluster research-program 1999-2002 (ICES-KIS-II), that consists of 7 research themes:
► Soil and structures, ► Risks due to flooding, ► Coast and river, ► Urban infrastructure,
► Subsurface management, ► Integrated water resources management, ► Knowledge management.

This publication is part of:

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Delft Cluster is an open knowledge network of five Delft-based institutes for long-term fundamental strategic research focussed on the sustainable development of densely populated delta areas.

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**Project Group**

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