

# COMP-533

## Model-Driven Software Development

### Course Outline

#### Instructor

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#### Course Homepage

On myCourses.

#### Course Contents

*Model-Driven Engineering* (MDE) is a unified conceptual framework in which the whole software life cycle is seen as a process of *model production*, *refinement* and *integration*. Models are built representing different views of a software system using different *formalisms*, i.e. modelling languages. The formalism is chosen in such a way that the model concisely expresses the properties of the system that are important at the current level of abstraction. During development, high-level specification models are refined or combined with other models to include more solution details, such as the chosen architecture, data structures, algorithms, and finally even platform and execution environment-specific properties. The manipulation of models is achieved by means of *model transformations*. Model refinement and integration continues until a model is produced that can be executed. This model can take the form of source code, but does not need to.

This is a graduate course that targets both advanced undergraduates and project masters who want to learn standard techniques and methodologies applied in industry, but also master thesis and Ph.D. students who are interested in hearing about advanced research topics in MDE.

#### Standard MDE Notations and Methodologies

The object-oriented software development industry has gone through the process of standardizing visual modelling notations. The Unified Modelling Language (UML), a modelling language for specifying, visualizing, constructing, and documenting, is the product of this effort; it unifies the notations that currently exist in the industry. Therefore, every computer scientist, and especially every software engineer should have had contact with UML during his or her studies. Using UML notations has many benefits, including:

- It offers a common language uniting different object-oriented software development methodologies in terms of notation and vocabulary.
- It provides a rich set of notations that can be used to describe many different aspects of the software under development, including complex concurrency and distribution.
- It contains extension mechanisms and a constraint language called the Object Constraint Language (OCL). OCL is based on standard set-theory and is free of side-effects. It can be used to place additional constraints on models and describe pre- and postconditions of operations.
- UML provides a semantic base in the form of a metamodel that defines well formed models, and possible relationships between models and model elements.
- UML is a OMG standard.
- It allows tool interoperability between different vendors.

However, UML is only a language: it is process independent and therefore does not prescribe how and when during the software development cycle its notations should be used. Using UML to model software systems still requires a method - a choice of models and a process of their elaboration.

The goal of the standards part of this course is to expose the students to a rigorous UML-based software development method. The emphasis of the course is on how to put the different pieces of the UML puzzle together, i.e. which UML notations are the most appropriate to model the system under development within each software development phase. It teaches the students how to choose a coherent subset of UML to produce complete and consistent analysis and design models, and in which order the different models should be produced, and how models from one development phase are used as input / transformed into models at the next development phase.

The course teaches Fondue, a UML extension of the second-generation object-oriented development method Fusion (Hewlett Packard). Fondue uses a coherent subset of UML to establish complete and precise analysis and design documents for a software system. Fondue's requirements engineering is based on use cases. The analysis phase establishes a Domain, a Concept, an Environment, a Protocol, and an Operation Model. During design, a Design Class Model, an Object Interaction Model, a Dependency Model and an Inheritance Model are constructed. Finally, Java-specific mapping strategies lead to the system implementation.

Most models use graphical UML notations (e.g. class diagrams, object-interaction diagrams, state diagrams). The course covers these UML notations in detail. In addition, a major part of the lectures present how to elaborate one model based on the others, and ensure completeness and consistency among the different views. When the graphical notations are not strong (or "formal") enough to produce a precise model, the models are augmented using the Object Constraint Language (OCL). OCL is a formal, set-theory based language that allows software engineers to augment UML models with additional constraints, or state preconditions, postconditions and invariants of operations in a precise way.

## Advanced MDE / Concern-Oriented Reuse

Model-driven engineering advocates to use the most appropriate modelling formalism(s) at each development phase to express the concerns at hand, and it turns out that UML is not always the most appropriate language. The crosscutting nature of most development concerns makes it difficult to apply in a modular way software engineering techniques, such as, information hiding, decomposition, interfaces, and abstraction, in standard modelling languages such as UML. As a consequence, reuse – in particular model reuse – is a challenge in MDE.

The second part of this course will introduce the students to more advanced modelling notations and domain-specific modelling in order to expose them to current state-of-the-art modelling techniques and tools. In particular, I am planning to focus this year also on Concern-Oriented Reuse (CORE), a novel reuse paradigm that extends Model-Driven Engineering (MDE) with best practices from advanced modularization and separation of concerns techniques, goal modelling, and Software Product Lines (SPL). CORE advocates the use of a three-part interface to describe a new unit of reuse called *concern* that spans multiple development phases and encapsulates all software engineering artifacts (models, code) needed to address specific software development issues. While developing an application, whenever a specific development issue is encountered, the developer can browse the reusable concern library in search for a concern that addresses the issue. If found, CORE defines a simple three-step reuse process

that a) helps the developer decide on the most appropriate of the solutions provided by the concern for the current reuse context, b) indicates to the developer where and how to adapt the software artifacts provided by the concern to the reuse context, and c) specifies how to correctly make use of the functionality provided by the concern.

Due to the fact that most (if not all) software development concerns are of crosscutting nature, concern designers must use modelling notations that support aspect-oriented features to design the models that encode the solutions for addressing the concern. For example, for requirements elicitation and analysis, the User Requirements Notation (URN) and AoURN, its aspect-oriented extension are going to be shown in class. For software design modelling, the Reusable Aspect Models notation that provides aspect-oriented variants of class, sequence and state diagrams, will be explained.

## Tentative Course Schedule

### Course Overview

- Introduction
- UML and Fondue Method Overview
- Reuse, Separation of Concerns

### Requirements Elicitation

- Object-Orientation and Aspect-Orientation
- Use Cases
- Domain Model
- Feature Models
- Goal Models
- Specifying the Variation Interface of a Concern

Notations covered: Use case diagrams, class diagrams, feature models, goal models

### Analysis

- Concept Model
- Environment Model
- Protocol Model
- OCL
- Operation Model
- Check of Analysis Models
- Creating Requirements Realization Models for Concerns

Notations covered: Class diagrams, interaction diagrams, use case models (UCM and AoUCM), the Object Constraint Language

## Design

- Interaction Model
- Dependency Model
- Design Class Model
- Inheritance Model
- Reusable Aspect Models
- Principles of Good Design / Design Patterns
- Creating Design Realization Models for Concerns

Notations covered: Sequence diagrams, class diagrams, state diagrams, Reusable Aspect Models

## Implementation

- Implementation Class Model
- Mapping to Java

## Reading List and Handouts

All course slides and exercises will be made available for download on the course webpage.

### Most Useful Textbook

- Craig Larman. Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design. First Edition, Prentice Hall 1998. ISBN: 0137488807

Note: The new “second and third editions” of the book are based on the Rational Unified Process (RUP), rather than the Fusion process.

### Other Textbooks

#### Fusion

The following book describes the Fusion object-oriented development method. (Fondue is based on Fusion, but uses the UML notation. Therefore, diagrams presented in these books will seem unfamiliar.) The book has also been translated into French.

- English Version: D. Coleman, P. Arnold, S. Bodoff, C. Dollin, H. Gilchrist, F. Hayes and P. Jeremaes. Object-Oriented Development - The Fusion Method. Prentice Hall, 1994.
- French Version: D. Coleman, P. Arnold, S. Bodoff, C. Dollin, H. Gilchrist, F. Hayes et P. Jeremaes. Fusion: la méthode orientée objet de 2ème génération. Masson, 1996.

### UML Reference Manual

- James Rumbaugh, Ivar Jacobson and Grady Booch. The Unified Modelling Language Reference Manual. 2nd edition. Object Technology Series, Addison Wesley, 2004. ISBN: 0-321-24562-8

Download the UML specification from the web!

## OCL

- Jos Warmer and Anneke Kleppe. The Object Constraint Language - Getting your models ready for MDA, 2nd edition. Object Technology Series, Addison Wesley, 2003. ISBN 0-201-37940-6

## Prerequisites

- COMP-303 Software Design, or
- ECSE-321 Introduction to Software Engineering, or
- Consent from the Instructor

## Course Format

The course will be offered in the traditional lecture format, i.e. 3 hours of lectures per week.

## Grading

There will be graded homework assignments (2 \* 15%), a mid-term exam (30%), and a project (probably split into a 15% and a 25% hand-in).

## Academic Integrity:

McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures (see [www.mcgill.ca/integrity](http://www.mcgill.ca/integrity) for more information).

L'université McGill attache une haute importance à l'honnêteté académique. Il incombe par conséquent à tous les étudiants de comprendre ce que l'on entend par tricherie, plagiat et autres infractions académiques, ainsi que les conséquences que peuvent avoir de telles actions, selon le Code de conduite de l'étudiant et des procédures disciplinaires (pour de plus amples renseignements, veuillez consulter le site [www.mcgill.ca/integrity](http://www.mcgill.ca/integrity)).

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