An IDE to Build and Check Task Flow Models

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Abstract. This paper presents the Eclipse plug-ins for the Task Flow model in the Discovery Method. These plug-ins provide an IDE for the Task Algebra compiler and the model-checking tools. The Task Algebra is the formal representation for the Task Model and it is based on simple and compound tasks. The model-checking techniques were developed to validate Task Models represented in the algebra.

Keywords: lightweight formal specification; software modelling; model-checking.

1 Introduction

There has been a steady take up in the use of formal calculi for software construction over the last 25 years [1], but mainly in academia. Although there are some accounts of their use in industry (basically in critical systems), the majority of software houses in the "real world" have preferred to use visual modelling as a kind of "semi-formal" representation of software. A method is considered formal if it has well-defined mathematical basis. Formal methods provide a syntactic domain (i.e., the notation or set of symbols for use in the method), a semantic domain (like its universe of objects), and a set of precise rules defining how an object can satisfy a specification [11]. In addition, a specification is a set of sentences built using the notation of the syntactic domain and it represents a subset of the semantic domain. Spivey says that formal methods are based on mathematical notations and "they describe what the system must do without saying how it is to be done" [10], which applies to the non-constructive approach only. Mathematical notations commonly have three characteristics:

– conciseness - they represent complex facts of a system in a brief space;
– precision - they can specify exactly everything that is intended;
– unambiguity - they do not admit multiple or conflicting interpretations.

Essentially, a formal method can be applied to support the development of software and hardware. This paper shows an IDE for modelling and checking task flow models using a particular process algebra, called Task Algebra, to characterise the Task Flow models in the Discovery Method. The advantage is that this will allow software engineers to use diagram-based design methods that have a secure formal underpinning.

1.1 The Discovery Method

The Discovery Method is an object-oriented methodology proposed formally in 1998 by Simons [8, 9]; it is considered by the author to be a method focused mostly on the technical process. The Discovery Method is organised into four phases; Business Modelling, Object Modelling, System Modelling, and Software Modelling (Simons, pers. comm.).The Business Modelling phase is task-oriented. A task is defined in the Discovery Method as something that "has the specific sense of an activity carried out by stakeholders that has a business purpose" (Simons, pers. comm.). This task-based exploration will lead eventually towards the two kinds of Task Diagrams: The Task Structure and Task Flow Diagrams. The workflow is represented in the Discovery Method using the Task Flow Diagram. It depicts the order in which the tasks are realised in the business, expressing also the logical dependency between tasks. While the notation used in the Discovery Method is largely based on the Activity Diagram of UML, it maintains consistently the labelled ellipse notations for tasks.

1.2 The Task Flow models

Even though Task Flow models could be represented using one of the process algebras described above, a particular algebra was defined with the aim of having a clearer translation between the graphical model and the algebra. One of the main difficulties with applying an existing process algebra was the notion that processes consist of atomic steps, which can be interleaved. This is not the case in the Task Algebra, where even simple tasks have a non-atomic duration and are therefore treated as intervals, rather than atomic events. A simple task in the Discovery Method [8] is the smallest unit of work with a business goal. A simple task is the minimal representation of a task in the model. A compound task can be formed by either simple or compound tasks in combination with operators defining the structure of the Task Flow Model. In addition to simple tasks and compound tasks, the abstract syntax also requires the definition of three instantaneous events. These may form part of a compound task in the abstract syntax.

2 The Task Flow metamodel

2.1 The Task Algebra for Task Flow models

The basic elements of the abstract syntax are: the simple task, which is defined using a unique name to distinguish it from others; ε representing the empty activity; and the success σ and failure φ symbols, representing a finished activity. Simple and compound tasks are combined using the operators that build up the structures allowed in the Task Flow Model. The basic syntax structures for the Task Flow Model are sequential composition, selection, parallel composition, repetition, and encapsulation. The algebra definition is shown in table 1.

$Activity ::=$	ε	– empty activity
	$\mid \sigma$	– succeed
	$\mid \varphi$	– fail
	$\mid Task$	– a single task
	$\mid Activity; Activity$	– a sequence of activity
	$\mid Activity + Activity$	– a selection of activity
	$\mid Activity \parallel Activity$	– parallel activity
	$\mid \mu x.(Activity; \varepsilon + x)$	– until-loop activity
	$\mid \mu x.(\varepsilon + Activity; x)$	– while-loop activity
$Task ::=$	$Simple$	– a simple task
	$\mid Activity$	– encapsulated activity

Table 1. abstract syntax definition

A task can be either a simple or a compound task. Compound tasks are defined between brackets '{' and '}', and this is also called encapsulation because it introduces a different context for the execution of the structure inside it. Curly brackets are used in the syntax context to represent diagrams and sub-diagrams but also have implications for the semantics. Also, parentheses can be used to help comprehension or to change the associativity of the expressions. Expressions associate to the right by default. More details of the axioms can be seen in [6].

2.2 Model-checking

A set of traces is the trace semantic representation for a Task Flow Diagram. The verification of the diagram may be made in different ways. The simplest operations could be performed by set operators but more operations may be applied over the traces using temporal logic. Temporal logic has being extensively applied with specification and verification of software. The set of traces, obtained from a task algebra expression, may be used to verify some temporal and logical properties within the specification expressed by the diagrams. For this reason, a simple implementation of LTL was built. This LTL implementation works over the trace semantics generated from a Task Algebra expression. Because the trace semantics represent every possible path of the Task Flow diagram expressed in the Task Algebra, it is straightforward to use LTL formulas to quantify universally over all those paths. In this section, some examples using Linear Temporal Logic (LTL) are presented, to illustrate the reasoning capabilities of the LTL module. LTL is a temporal logic, formed adding temporal operators to the predicate calculus. These operators that can be used to refer to future states with no quantification over paths. In addition, a CTL application was built to test CTL theorems against expressions in the task algebra. In this case, the application has to transform the traces in a tree representation before applying the expression. While LTL formulas express temporal properties over all undifferentiated paths, Computational Tree Logic (CTL) also considers quantification over sets of paths. CTL is a branching-time logic [5] and theorems in this logic may also be tested against a set of traces obtained from a task algebra expression, in the same way that LTL theorems were tested above.

3 A tool for formal specification of Task Flow models

3.1 Analysis of Integrated Development Environments (IDE)

Through a search in surveys and articles published in digital media, Eclipse is chosen as the top two open source IDEs best positioned among developers. However, Eclipse showed a better performance due to the existence of robust tools for the development of plug-in, as it has with the Plug-in's Development Environment (PDE) which provides tools to create, develop, test, debug, build and deploy Eclipse plug-ins, modules and features to update the sites and products Riched Client Platform (RCP). PDE consists of three elements:

- PDE User Interface (UI) for designing the user interface;
- PDE Tools Application Programming Interface (API Tooling) useful pieces of code to develop applications;
- PDE Builder (Build), manager responsible for the administration of the plug-in.

Besides all this, the GMF frameworks (Graphic Modeling Framework - Framework for graphic editing) and Eclipse Modeling Framework (Eclipse Modeling Framework, EMF), which facilitate the construction. We can get a highly functional visual editor using EMF to build a structured data model enriched by GMF editors. The main advantage is that being all development based on building a structured model, the time spent on the maintenance phase will be substantially reduced.

3.2 The architecture of the task model tool

As mentioned above, our general architecture is based on the Eclipse framework. The first component is able to model Task Flow diagrams and translate them into a metamodel formed by Task Algebra expressions. The resultant file containing the metamodel is used by the Task Algebra compiler in order to generate the trace semantics.

In addition, the other component in Eclipse has the responsibility to receive LTL and CTL queries. The queries are sent to the relevant model-checking tool. Textual results are returned by the tool and have to be interpreted by LTL/CTL Eclipse plugin. Figure 1 shows the general dependency between the components of our project.

4 Formal modelling made easy

4.1 Design of the structured model

Once identified the use cases, classes were designed including the interaction between different objects of the tool, we then proceeded to design the structured

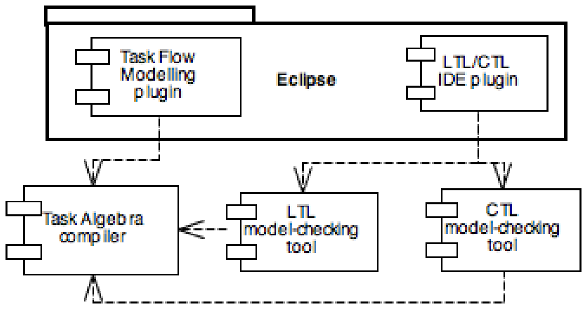


Fig. 1. Architecture of the Task Model Tool.

model. This model is presented in Figure 2. All development of the structured model is based on the use case diagram, when we should be extra careful as it migrates from an abstract model such as use cases and results in a diagram from which one has the possibility of building the computer application as such, in this case, set the application logic. Note that only cover part of the user interaction.

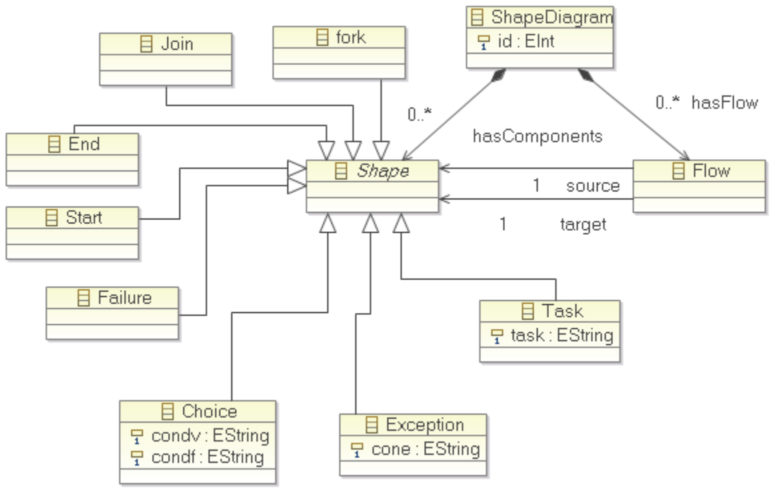


Fig. 2. Class model for the Task model plug-in,based on GMF.

4.2 Development of the graphical model

When the structured model is designed properly [2, 3], this can be transformed to the model graph. The model is a set of classes that represent real-world information. In our case, the components which are integrated with diagrams. For example, the Choice component, is associated with a specific behaviour, therefore we need to store some additional information (i.e, this component implies information for the guards that will trigger the flow). All this without taking into account neither the manner in which that information will be displayed nor the mechanisms that make these data are part of the model; i.e., without regard to any other entity within the plug-in.

4.3 The domain model

The domain model (or the model itself) is the set of classes resulting from analysing the components needed to design a task flow diagram. Start, Task, Fork, Join, Exception, Failure, Choice and End are the classes that were defined for the domain model. The domain model is not related to external information, we have an overview of the components of each one of its elements.

4.4 The application model

The application model is a set of classes that are related to the domain model, are aware of the views and implement the necessary mechanisms to notify the latter on the changes that might give the domain model. The EMF framework, is responsible for this functionality, and which interacts directly with the structured model; i.e., the model built on EMF.

4.5 The view domain

The views are the set of classes that are responsible for showing the user the information contained in the model. A view is associated with a model. A view of the model gets only the information you need to deploy and is updated each time the domain model changes through notifications generated by the model of the application. GMF is responsible for receiving such notifications and for generating visual feedback on the plug-in.

4.6 The driver

The driver is an object that is responsible for directing the flow of enforcement due to external messages and requests generations of the algebra. From these messages, the controller modifies the model or open and close views. The controller has access to the model and views, but the view and the model are not aware of the existence of the controller. The controller itself is the result of the implementation code from the developer, which using GMF has the ability to interact with information from the visual editor plug-in. This operation is given by the $IWorkbenchWindowActionDelegate$ class implementation.

4.7 Integration

Finally when the two models have been integrated, we get almost all of the user interface plug-in. It is at this point when we have to develop the capabilities to manage graphics' performance and integration with the components of the translator (i.e., the logic implementation, where specific individual components).

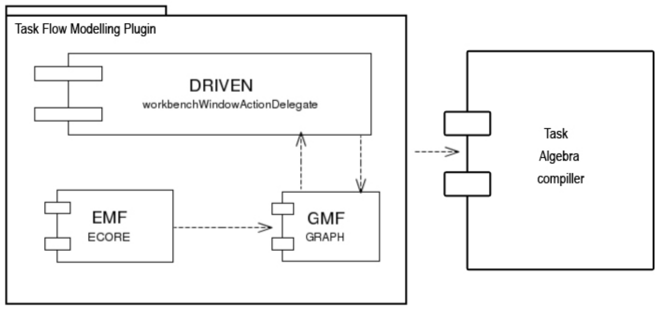


Fig. 3. View of integration and dependency of the plug-in for development of tasks diagrams.

4.8 Results

At this point we have obtained a comprehensive user interface, that is, the party responsible for managing the design process diagrams. It is worth noting that the code implementation has been rather small, since everything is generated from structured model. Up to this point we have managed to cover about half of the project. Figure 4 shows a screen user interface of this part of the project so far.

The development of application-based models implemented in the various tools for creating plug-ins, as is the Plug-in Development Environment, has resulted in optimization of time. The most important point is the possible modification, addition, facilitation and exploration of the plug-in, because you can just modify the structured model and its subsequent integration with GMF model to make accurate changes, all without writing a single line of code, so it is found that the design of the model implemented in a tool is superior to developments made entirely in code.

5 LTL que and CTL model-checking IDE

5.1 Verification Interface of Task Flow diagrams in the software specification

Some factors influencing the development of quality software are: Understanding of requirements, proper modeling of the use cases, verification of models and

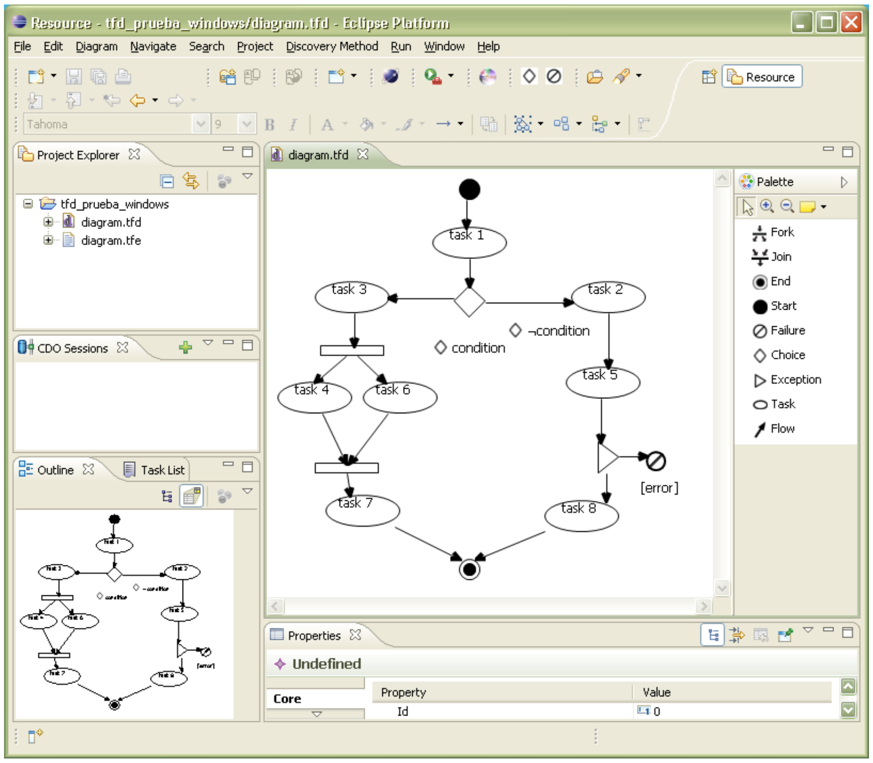


Fig. 4. Partial view of user interface for the Task Model plug-in.

development according to user needs. Task Flow diagrams from the Discovery Method are represented by a reduced and precise syntax. The verification over the Task Flow diagrams is performed using temporal logic functions. The most common temporal logics are Linear Temporal Logic (LTL) and Computational Tree Logic (CTL)[4]. The temporal logics are applied on an exhaustive set of states to see if a specification is true or not through time, it ensures verification of dynamic properties of a system without introducing time explicitly[7]. The Task Algebra proposed by Fernandez [6] offers already the tools (text mode) allowing you to verify Task Flow diagrams specified by the Discovery Method using temporal logic. This tool in text mode does not involve a visual representation of the operation and the logical transition of the model and it does not allow a full analysis of the results. The construction of an interface that allows to structure LTL/CTL queries and to graphically display results of the model verification represents the solution of the problem.

With the development of an interface to verify task diagrams, the user will have on hand a structured visual tool that lets him/her create logical expressions to refer to events in the algebraic model of work flow and display query results in a more meaningful and understandable way. With the creation of these components the Task Algebra will become more accessible and with the help of appropriate technologies it will represent a contribution to the specification and design phase in software development.

5.2 Development Process

The flow of activities in the design phase can be modeled by Task Flow diagrams, which in addition to its graphical representation has a formal syntactic model. The formal model of the task diagrams is the basis for verification of system properties. The structure of a logical query(LTL/CTL) is complex, therefore it is necessary to assist it in the construction and comprehension of these expressions, as well as in the visualization of results.

Considering the ease of development, usage statistics and features offered in development environments, the interface of verification will be integrated as a plug-in in the Eclipse development environment. For best results, interface, testing and monitoring is necessary to take into consideration the following definitions for the task diagrams verification process:

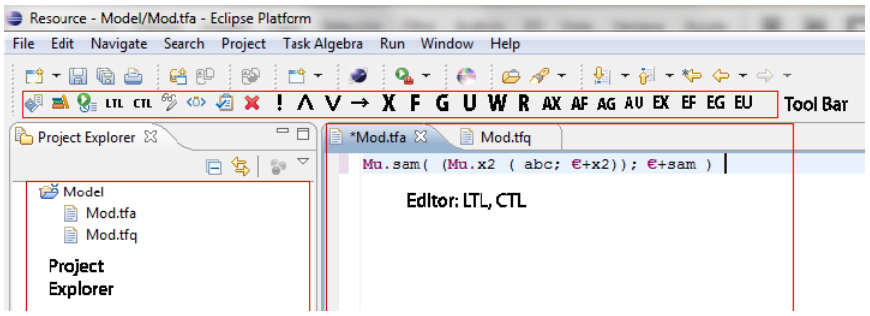
– The plug-in should check the entry model that describes the task algebra.
– There should be a check of logical expressions created (LTL and CTL syntax).
– The test results should be displayed in an easy and simple way for user understanding.
– The verification interface should be efficient and effective.

Among the verification characteristics of the input model and the expressions syntax is used XText. In order to verify the input model and the syntax of the expressions we use XText. With XText, domain-specific languages (DSL) can be created in a formal and simple way. The framework supports the development of infrastructure in languages including compilers and interpreters and currently it has joined the Eclipse development environment. In interface development, Eclipse's core libraries such as org.eclipse.ui, org.eclipse.jface and org.eclipse.core are used. These packages allow to integrate icons and complete editor management, results in the interface development are shown in figure 5. As we can see, the task diagrams verification interface consists of the following elements: module expressions, work area and input models.

5.3 Modules Interactivity and Results

The input for this plug-in is a Task Algebra expression representing the Task Flow metamodel (see Figure 6a). This metamodel is used to generate the trace semantics needed to execute the query. A query construction is created and stored when the user builds LTL or CTL logical expressions (see Figure 6b).

The algebra model (tfa) and logical expressions created (tfq) are verified in continuous time using DSL grammars defined in the plugin (XText), which produces syntactically correct expressions. Combining the algebra model and


Resource - Model/Mod.tfa - Eclipse Platform
File Edit Navigate Search Project Task Algebra Run Window Help
LTL CTL ! ∧ ∨ → X F G U W R AX AF AG AU EX EF EG EU
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Mod.tfq
Project Explorer
*Mod.tfa
Mod.tfq
Editor: LTL, CTL

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Mu.sam( (Mu.x2 ( abc; €+x2)); €+sam )
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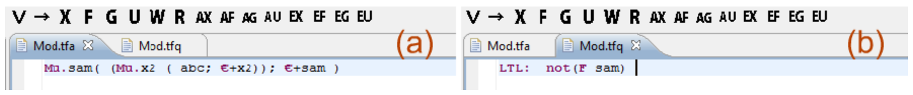
Fig. 5. Partial view of user interface for the model-checking plug-in: DSL Grammars, graphics elements and editor management.



```
Mu.sam( (Mu.x2 ( abc; €+x2)); €+sam )
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LTL:  not(F sam)
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Fig. 6. Partial view of the user interface for the model-checking plug-in: (a) describing a Task Flow diagram, (b) describing logical expressions.

the correct logical expressions, the verification of properties in the model is executed using the text mode tool described in [6]. This part of the project is also responsible of the graphical display of the results. This is still a work in progress but it is considered relevant in order to facilitate the interpretation of the query results. In particular, the CTL results are the most difficult to understand in their present form.

6 Conclusions

Being Eclipse one of the most used environments for software development, we offer a tool that allows modelling and testing of software models that are defined usually in the specification phases. Our research presented the Eclipse plug-ins for the Task Flow model in the Discovery Method. The task algebra is based on simple and compound tasks structured using operators such as sequence, selection, and parallel composition. Recursion and encapsulation are also considered. The task algebra involves the definition of the denotational semantics for the task algebra, giving the semantics in terms of traces. Additionally, model-checking techniques were developed to validate Task Models represented in the algebra.

All of these was already available as console tools to prove the feasibility of the propose but, in order to be used by real-world developers, an IDE was necessary. With these tools, developers are not required to increase the quantity of artifacts when developing software. If developers create Task Flow diagrams, they will have an formal specification for their software which could improve communications using the unambiguous notation. In addition, using software model-checking in early stages may increase the confidence that goes from a correct definition to the final design. The plug-ins developed facilitate the formal specification of the Task Flow models and the verification of these models in a visual and simple way. The queries are structured visually and with it the interpretation of results is even more simple. With this project the development time has been optimized and the quality of software has been guaranteed. In this project every module is easy to use and to understand for programmers due to its integration with Eclipse.

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