Model-Driven Development

Piecing Together the MDA Jigsaw Puzzle

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The MDA paradigm [21] is extensively used by the software engineering (SE) community. There are a large number of methods, such as USIXML [33] or OOWS [14], that are based on the MDA paradigm and that apply model transformations during the development process.

The MDA paradigm proposes several models to represent the system. Each model describes the system from a different abstraction level. According to MDA, the first model to be built during the software development process is the computation-independent model (CIM). The CIM is a viewpoint focused on the environment and system requirements; it disregards the computerisation of the system being modelled. The next level of abstraction is called the platform-independent model (PIM). This model takes into account which parts of the system will be computerised, but it still does not determine the technological platform that will support the implementation. After these models have been built, a platform-specific viewpoint is needed. This layer is called the platform specific model (PSM) and it describes the system attending to the specific characteristics of the platform that will support it. Finally, the code model is derived from the PSM. Transformations among all these MDA models are (semi)automatic, depending on the MDA environment that supports them. Moreover, some MDA environments implement MDA models with a combination of several models. The route from the CIM to the final code can be quite tortuous, because the analyst has to construct a large number of models.

Furthermore, depending on a number of contingencies, the sequence in which the analyst fills out the models may change. For example, a CIM can be composed of several requirements models. The order in which they are built may be determined by the type of user that is formulating the requirements. Certain requirement models may be more appropriate for initiating capturing requirements with an expert computer user than others.

One contribution of this paper is to show that there are various ways of automatically generating the final code in an MDA environment called the OO-Method [27]. The OO-Method is a software development method that models the system at different abstraction levels, distinguishing between problem space (the highest abstract level) and solution space (the lowest abstract level). The software generation process of the OO-Method is shown in Fig. 1. This figure also shows the correspondence between each OO-Method model and the MDA models. It is important to note here that some models belonging to the same stage in the OO-Method software development process correspond to different MDA models. This issue will be discussed in Sect. "The MDA Jigsaw Puzzle and the OO-Method". Each OO-Method model can be seen as a piece of a jigsaw puzzle that has to fit together with the rest, depending on a number

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Abstract

The model-driven architecture (MDA) paradigm is well-known and widely used in the field of model-based software development. However, there are still some issues that are problematic and that need to be dealt with carefully. In this paper we present a metaphor that explains how MDA grows in complexity as problems faced become more difficult or "wicked", and how a method designed to be powerful, flexible and MDA-compliant can eventually become, in effect, a "jigsaw puzzle". This jigsaw puzzle is not merely the result of having a collection of methodological "pieces" with routes across them, but also arises as a result of the criteria underlying the MDA abstraction layers. We compare MDA to other research fields such as human-computer interaction, model management and method engineering, and we use as an example the OO-Method, a software development method based on MDA-compliant model transformations. We focus on a methodological piece that is conceived to allow the specification of interaction requirements by means of interface sketches. These sketches are supported by a task model that serves as a sound basis for formalisation and allows the application of model transformation in order to obtain subsequent models. A case study illustrates the requirements capture method together with the software development process defined by the OO-Method. The whole process presented in the case study represents one of the possible routes that can be followed when developing a software system with the OO-Method.

of factors. All pieces together represent the system being built.

From all the pieces that compose the OO-Method jigsaw, this work focuses on the pieces (models) that capture interaction requirements, which are very important non-functional requirements when producing high-quality software. A system with an inadequate interaction is likely to be rejected by the user, even though the system is functionally correct. Many MDA-based approaches disregard interaction requirements; in doing that, we argue, they disregard a key factor for success.

Our proposal to capture interaction requirements is based on a formal notation proposed by Paternò called ConcurTaskTree (CTT) [28]. A task defines how the user can reach a goal in a specific application domain. The main reason for using this notation is the fact that it is a formal language that provides a formal semantic, makes the model verifiable, and avoids ambiguity in the specification.

However, creating task trees during requirements modelling is an arduous endeavour. This notation is not friendly with regard to medium-sized systems. For this reason, this paper proposes to superimpose a more manageable model over the task trees (although it adds a new piece to the jigsaw puzzle). The proposed model is based on sketches, i.e. drawings that represent the final system interface. Each part of a sketch corresponds to a part of a CTT tree. In order to guarantee the correspondence between sketches and CTTs, syntactic rules have been defined. These rules limit the degree of freedom when producing the sketches, but they allow derivation of the CTTs from the sketches. CTTs are synchronously created while the analyst is creating the sketches.

To accomplish these goals this paper is structured as follows. Section "Related Works" shows a set of related works based on method engineering and interaction requirements capture. Section "The MDA Jigsaw Puzzle and the OO-Method" reflects on the complexity of using MDA methods with their multiple models and multiple routes for modelling, and the MDA jigsaw metaphor is introduced. Section "A Method for Capturing Interaction Requirements: Sketches" focuses on interaction requirements capture. Section "Case Study" shows a case study using the pieces of the OO-Method jigsaw puzzle that support user-system interaction modelling. Finally, Sect. "Conclusions and Future Work" provides our conclusions and outlines possible future work.

Related Works

This work is related to the application of situational method engineering to requirements elicitation, alternative routes for following the OO-Method, and capturing interaction requirements by means of sketches. In this section a brief review of these related works is presented.

Method engineering represents a structured framework in which methods for software devel-

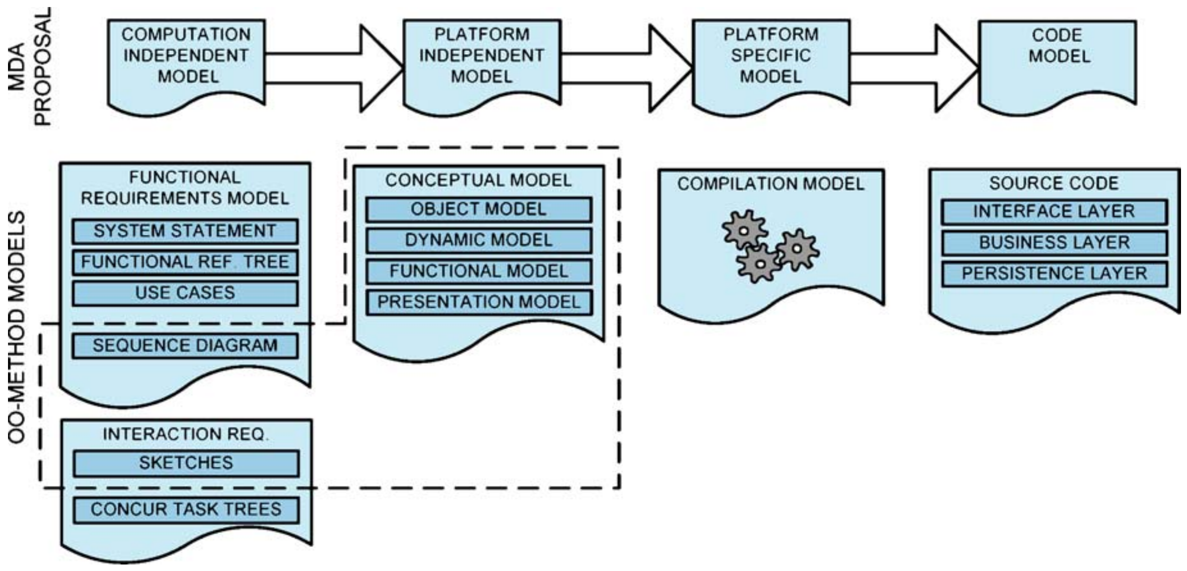


Fig. 1 Comparison between MDA and the OO-Method

opment activities can be designed, constructed, and adapted. Methods are assembled from multiple individually identifiable parts, often referred to as "method fragments" or "method chunks". Situational method engineering is therefore the configuration of these resultant methods specifically for individual projects [5]. This topic is especially relevant and useful in areas such as requirements engineering where various situation-specific factors, e.g. project objective, application domain, features of the product to be developed, stakeholders involved, and technological conditions and constraints, exert a significant influence [2].

Ågerfalk and Ralyté [2] have identified an initial and traditional assembly-based approach in method engineering. In their work the procedure was used to describe methods and processes in meta-models to be used as a basis for computer supported instantiation of situational methods, typically through the assembly of a number of method fragments from different methods stored in a method base [6, 20]. Recently, however, method engineering research and practice have extended beyond the traditional assembly-based approach to address a variety of issues including method requirements specification [15], method configuration [17] and roadmap-driven approaches [22]. Recent works [1, 18] also pay more attention to method rationale (i.e. the reasons behind and arguments for the method) and the tension between method-in-concept (as described in method handbooks) and method-in-action (as enacted in actual engineering practice).

Taking into consideration the ideas behind situational method engineering and requirements engineering, this paper is a first step to analyze different routes or directions taken when following the OO-Method. This is where a useful connection can be made between MDA and situational method engineering. Different starting points in the requirements phase, as well as different routes for continuing the software development process, could represent an improvement, depending on the characteristics of the specific project to be developed. In this work, the analysis is limited to possible alternatives, but always within the same software development method: the OO-Method.

Regarding interaction requirements, it can be said that no widely accepted method for capturing them currently exists, and that the drawing of user interface sketches is becoming more important in this field. A significant variety of tools now exist for drawing interface sketches which are then used to automatically (or semi-automatically) generate the final interface.

DEMAIS [3] and DENIM [25] are tools for designing a particular kind of application. DEMAIS was specially designed for multimedia applications design. This tool allows the designer to shape interaction and temporality ideas and to see the result obtained. DENIM helps website designers in the preparation of sketches at different levels: site map, storyboard and individual pages. The levels are unified through views.

On the other hand, more general tools exist for designing any type of application. One of these tools is SILK [19], which provides four primitives: rectangle, free line, straight line, and ellipse. Interface prototypes are formed combining primitives. The designer can choose the interface components style once the tool has recognized each component (i.e. button type). Storyboards are used to illustrate navigation between interfaces. JavaSketchIt [7] uses a combination of simple figures for representing each possible widget (interface component). FreeForm [30] is another tool for creating sketches. Storyboards are used to navigate between sketches. The tool has an execution mode in which the user can test navigations, and offers a facility to align and determine a standard size for the created controls.

On one hand, all the previously presented tools generate code for a specific programming language which varies according to the tools. On the other hand, SketchiXML [9] generates user interface specifications in UsiXML [33], a platform-independent language for user interface description. This tool is able to advise the user about potential usability problems in the sketches that are produced. Besides, the figure representations can be configured by the user.

All the previously described tools share a common limitation: they only generate the software system interface, and in some cases, support navigation between interfaces. The approach proposed in this work was designed to be incorporated into a completely functional automatic code generation process, which uses a model compiler to generate not only the software user interface, but all the information system functionality too. Other relevant characteristics of the approach are the independence of the code language, which is generated to support different platforms.

The MDA Jigsaw Puzzle and the OO-Method

Software development methods usually offer several modelling techniques. The aim is that models complement each other and offer various perspectives on reality. In some cases, the complementary nature of the perspectives is horizontal. For example, aspect-oriented methods seek to segregate cross-cutting concerns that are observable at a certain abstraction level. In other cases, the complementary nature of the perspectives is vertical. The aim is to segregate the different abstraction levels of the descriptions. For example, data flow diagrams allow the level of detail of system descriptions to be increased by means of stepwise refinement. The four views of the OO-Method conceptual model (object, dynamic, functional and presentation models) also specify complementary perspectives on reality. For example, the functional model offers a horizontal complementary perspective with respect to the other three models. The functional model deals with aspects related to information system (IS) reaction while the other models specify IS memory and IS interface. However, the object model already has a dynamic part that structures IS reaction in terms of class methods. The functional model refines class methods by decomposition so, in this sense, it also offers a vertical complement to the object model. Further argumentation on the use of complementary perspectives can be found in [26].

The MDA paradigm proposes criteria to structure system descriptions in different layers. Having reached this point, a question arises: whether the complementary nature of the MDA layers is horizontal or vertical. MDA model definitions do not clarify this issue. Another question is whether the MDA criteria are pragmatic in real projects. As Fig. 2 depicts and we later argue, the MDA frontier between CIM and PIM layers cuts across the OO-Method requirements model diagonally. Figure 2 zooms in on the first two MDA layers shown in Fig. 1.

The MDA paradigm would be extremely easy and powerful if it were possible to follow a cascade software-development lifecycle. For this to work, one person would start building the models of the highest abstraction level. The subsequent models would then be manually or automatically derived, each time adding the details related to the new abstraction level. However, since reality is often very complex, the iterative and incremental development paradigm is more practical and popular. MDA adapts well to this way of working. One can start by modelling one part of the system and feeling one's way down the abstraction ladder. When this part of the system is more or less consolidated and perhaps even implemented and deployed, a new iteration starts. Another part of the system is modelled top-down. In an MDA-based iterative software

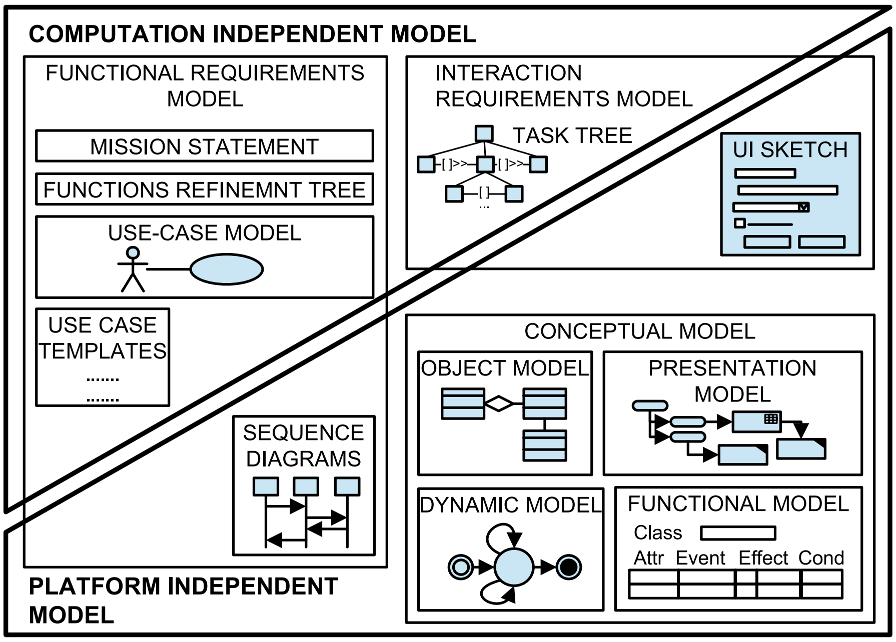


***Fig. 2** The MDA layers and the OO-Method: pragmatics going beyond frontiers*

development, either it is possible to partition the system with surgical precision, seeking a high cohesion and minimal coupling between the parts, or automatic transformations arise as a strong need.

Furthermore, in the area of ISs we often have to deal with so-called wicked problems. Wicked problems are often not fully understood until a solution has been found, since every wicked problem is essentially unique. Solutions to these problems are not right or wrong, simply "better", "worse", "good enough", or "not good enough" [31]. Indeed, it is the social complexity of these problems, not their technical complexity, which overwhelms most current problem-solving approaches. To appropriately deal with wicked problems, it is common to carry out opportunity-driven problem solving. At any given time the developers are seeking the best opportunity to progress toward a solution, regardless of whether they are going up or down in the abstraction ladder. Rittel [31] identified a type of problematic situation that can only be solved if representatives of all the stakeholders participate in a joint effort. Models are specifications of the shared knowledge about the problem and they serve as an agreement. Therefore, it is important that some specific models are understandable for the users.

The consequence of this tangle of cognitive, social and abstraction-level issues is that no single ingenuous solution is adequate. Methodologists need to offer software-development strategies that facilitate opportunity-driven problem solving. An evident corollary is that it is important to deal with contingency in software development. Methods must be flexible in the sense that the techniques to be applied in each moment are determined by various factors: the characteristics of the system to be computerised (i.e. automatic teller machines are not dealt with the same way as ISs), the nature of a specific problem presented at a given moment (e.g. to design a user interface, to specify business objects, to design strategic-level reports), the expertise of the development team (which techniques they know best), the maturity of the organisational system, the users' organisational and technological knowledge, the predisposition of the stakeholders to be involved in development, and so on.

With regards to the MDA paradigm, the number and variety of these issues give it a complexity akin to a jigsaw puzzle. Methodological confusion among practitioners appears, worsened by the fuzziness with which most methods and techniques are defined. Because of the lack of sound criteria, gurus proliferate, and practitioners try to make up for a lack of adequate methodological guides by generalising from examples and case studies. The solution to all of this, i.e. piecing together a well-founded method requires a number of issues to consider:

1. A theoretical soundness should be assured. This requires the basing of argumentations on unambiguous and well-defined concepts.
2. The usage of techniques should be specified. Modelling techniques are often offered by their authors as a panacea for all problems. Also, many modelling primitives can be used to describe things at different abstraction levels; techniques should be located in the methodological jigsaw puzzle, reducing the degrees of freedom with which they are marketed.
3. Method design that aims to facilitate opportunity-driven problem solving.
4. Provision is made for contingencies. This may be achieved by offering several alternative routes aimed at completing the methodological jigsaw puzzle. The routes should be appropriate for overcoming problems during complex projects.
5. To empirically assess all the alternative methodological routes. It is convenient to carry out a series of empirical tests to evaluate their viability, pros and cons.

We will now clarify the issues commented above with an example using some of the methodological pieces of the OO-Method (see Fig. 3). Firstly (issue 1), one way of gaining deeper knowledge about a method is to conceptually align it with an ontology, a set of well-defined related concepts. This ontology must be appropriate for the type of problem that will be solved using the method. For example, in [26] the OO-Method conceptual model is aligned with regard to a conceptual framework concerning information systems.

Each method must locate and place the pieces of its puzzle depending on the semantics associated with the modelling techniques being proposed (issue 2). For example, there is no consensus with regard to the criteria underlying use cases. As things stand, the rational unified process (RUP) proposes to distinguish between business use cases and (computerised system) use cases. In the case of the OO-Method functional requirements model, use cases are located at the CIM level (as the RUP business use cases), as Fig. 2 shows. This implies that no computerisation aspects should be considered at this level. Use case templates are also designed to be computation-independent. However, sequence diagrams decompose the IS in terms of objects that react to external and internal messages and many of them presuppose a computerisation of the system; for this reason, sequence diagrams in the OO-Method are not located at the CIM level, but rather at the PIM level. Particularly interesting is the case of the interaction requirements model. While task trees can be argued to focus on the interaction between the user and the system, it is still arguable whether the system refers to an information sys-

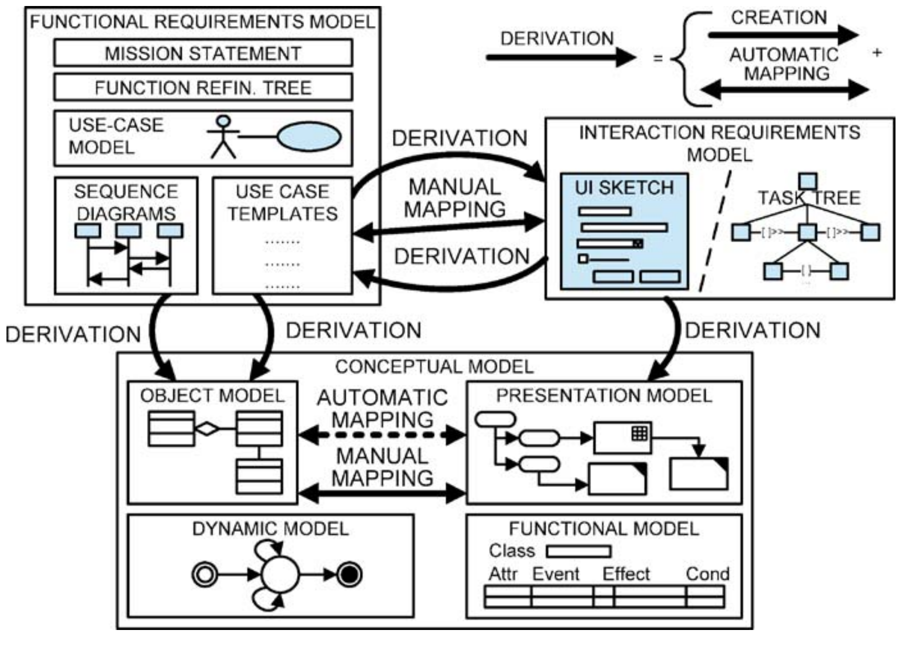


***Fig. 3** The MDA jigsaw puzzle in the OO-Method: aiming to support contingency*

tem or a computerised information system. In our proposal, the CTT notation is used as a computation-independent description of the interaction. By determining the semantics of each modelling primitive in a computationally independent way, we can fix the task model at the CIM. However, the sketch of the interface is evidently oriented towards a computerisation. Our sketching primitives are still independent of the particular programming and runtime environment, so the user interface sketches are claimed as part of the PIM. Figure 2 shows how the functional and the interaction requirements model are crossed diagonally by an MDA frontier.

In the OO-Method we confront the challenge in order to facilitate opportunity-driven problem solving (issue 3). We offer the chance to go up and down in the abstraction layers depending on the specific problems that the developers come across during a software project. Automatic transformations and the compilation of the conceptual model allow for an incremental development. Also, these transformations permit the testing and validation of partial solutions at a low cost. For a real opportunity-driven approach to be possible, the problem of inter-model incoherence must be dealt with. Sometimes a model B has been derived from a model A that is of a higher abstraction layer. Later, B is modified and details are added to it. Then it may occur that models A and B are no longer consistent. This problem is solved by round-trip engineering, that is, by offering support for the bottom-up propagation of changes in the models. In the case of the OO-Method conceptual model and the code model, the stress is put in the extreme non-programming paradigm [24], that is, no changes should be made to the code. However, current tools are not so refined, and when this is really needed, a Tweaking application solves the round-trip problem. Between the conceptual model and the requirements models, the round-trip problem is an issue still requiring a great deal of research, although some promising strategies are being tested.

When solving complex problems, contingencies must be dealt with appropriately. The development team may need to take different routes through the method (issue 4). All these methodological routes must be theoretically and practically achievable. Within the MDA paradigm, the routes usually involve manual derivations and (semi)automatic transformations among the models. In the OO-Method, we offer several routes (see Fig. 2). In the case of the OO-Method functional requirements model, the analyst can chose between describing use cases via specification templates or via sequence diagrams. The interaction requirements model is optional; it will not be necessary whenever the system being developed does not have demanding user interface requirements. However, it is recommended to specify the interaction requirements of those use cases that are not CRUD-like.[1] Furthermore, on some occasions, it is even convenient to start with the interaction requirements model for those parts of the system where the users already predispose some user interface sketches. This model then serves to establish a degree of shared knowledge between the users and the developers.

See Fig. 3 for a graph where the vertices represent the proposed models (methodological pieces) and the arcs represent transformations and mappings among the models. The core of the OO-Method is the conceptual model. Above it, at the functional requirements level, there are several proposals. In this paper we only present those proposals related to use cases. A different approach is described in [10], where the authors present an adaptation of BPMN to fit the OO-Method. The analyst will choose the most appropriate technique depending on the problem being solved (i.e. the system being developed). The OO-Method is also being extended at the lower abstraction levels. In order to give more expressiveness to the interface modelling, a concrete interface model [29] is being researched to deal with issues like widgets, alignment, look and feel, etc.

We can argue that our approach is theoretically valid. The different methodological routes are well-founded and the corresponding derivations and transformations are offered. However, not all of the routes necessarily give good results in all cases. We acknowledge that it is even possible that some routes are not convenient at all. This is closely related to empirical validation of methodological routes (issue 5). Evaluating situational methods (what we have called routes across the jigsaw puzzle) is one of the topics of interest of method engineering [13, 32].

[1] Create, read, update and delete are typical actions in information systems

For the sake of brevity, the following section focuses only on one of the OO-Method methodological pieces. Interaction modelling is chosen because it is still a pending issue in software engineering. To understand its context for use, in Sect. "Case Study" we offer an overview of a methodological route within the technique makes sense. The route starts with the functional requirements model (see Fig. 3). The use case templates branch is taken. Then the interaction requirements model is created; the interface sketches are manually mapped to the use case template. The derivation of the object model from use case templates is described in [11]. The strategy for deriving the presentation model from the interaction requirements model is described in [12]. Then a manual mapping could be carried out relating the presentation model and the object model. However, we are considering applying model management techniques and tools [4] to automatically obtain this mapping. Once the rest of the views of the conceptual model are created, the final application is automatically generated by a model compiler [8].

A Method for Capturing Interaction Requirements: Sketches

From all the pieces which compose the OO-Method jigsaw puzzle, this paper focuses on those pieces that specify the system interaction abstractly. This section proposes a method for capturing interaction requirements in an MDA environment. We have selected, as a starting point, the pieces of the OO-Method jigsaw puzzle devoted to interaction modelling due to the importance of modelling interaction to build usable systems. Following ISO 9126-1 [16], usability is a software characteristic that strongly influences software quality. Usability is related to modelling and implementing interaction according to user requests. Therefore, a requirements model to formally capture user interaction requests is appropriate.

The technique that the OO-Method proposes for capturing interaction requirements is based on Paternò's ConcurTaskTrees (CTT) [28]. The original grammar is extended to suit the OO-Method. This has the following layers:

– Lexical. This is provided by CTT notation (interaction tasks, system tasks, and abstract tasks).
– Syntactic. This is made up of structural task patterns that are structures of tasks related to each other by means of temporal operators.
– Semantic. This is provided by the correspondence between task patterns and model presentation patterns of the OO-Method.

Structural task patterns have been defined generically. Therefore, they offer arguments that are instantiated when patterns are used to model a specific interface. In the following figures, these arguments are shown in cursive format, indicating that their names and values should be instantiated. Arguments with variable cardinality are represented with ellipses (i.e. 1… *N*).

However, manual construction of these structural task patterns is very difficult, even though there is a tool to support the drawing thereof. Moreover, for small applications, the structural task patterns become illegible due to the huge number of CTTs that are created. This paper proposes a different abstraction level to represent the interface by means of sketches. The analyst, with the help of the user, draws sketches that represent the final interfaces. As the sketches are drawn, the structural task patterns are built automatically.

Sketches are an early model to represent the user interface. In order to define a new model, the first step is to establish a set of basic builders. In other words, the primitives for building up a sketch to represent the interface should be defined. The CTTs are built at the same time that the sketches are drawn. The second step is then to define a biunivocal relationship between sketch primitives and structural task patterns. For each structural task pattern, a sketch primitive is defined.

Therefore there are two models to represent system interaction, in other words, two pieces of the jigsaw puzzle to represent the interaction. On the one hand, CTTs have the advantage of being a formal language. A formal language provides a formal semantic, makes the model verifiable, and avoids ambiguity in specification. On the other hand, sketches are very simple. Therefore they are easy to create and can be understood by the final user.

For the sake of brevity, this work is based on the structural task patterns related to a list of instances (Population IU and the Elemental Patterns [23] related to it):

Filter. Filter primitives for sketches specify a filter criterion for the listed instances in the population. The analyst must place a symbol above the columns that the user wants to use in the filter (the letter F in Fig. 4). These marked columns instantiate the arguments of the corresponding structural task pattern.

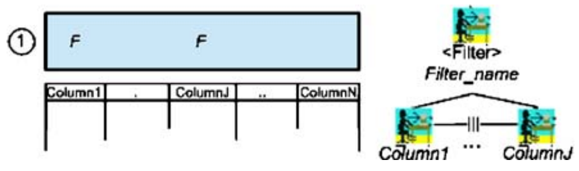


Fig. 4 Graphical primitive and structural task pattern for filter

Order criteria. The order criteria is defined in a manner similar to the filter primitive. Some symbols are placed above the columns (the letter O in Fig. 5) to order the listed instances. These symbols provide values for the arguments of the pattern.

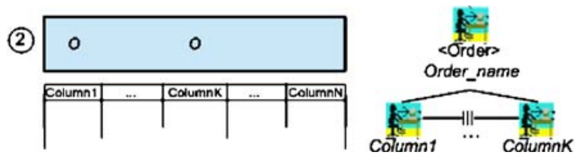


Fig. 5 Graphical primitive and structural task pattern for the order criteria

Actions. The actions, shown in Fig. 6, represent operations that can be made with the selected instance in the population list. Some actions are very common (i.e. create a new instance, modify it, or delete it); others are specific to the system that is being sketched. Actions instantiate the arguments of the structural task pattern.

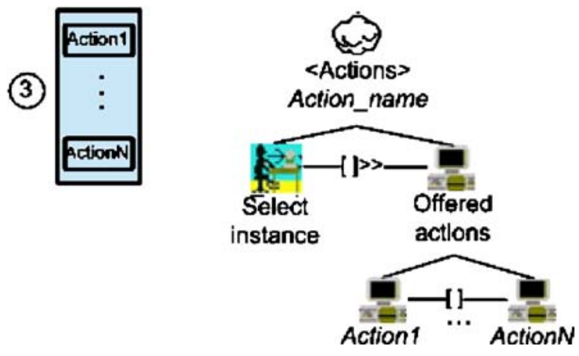


Fig. 6 Graphical primitive and structural task pattern for actions

Navigations. The analyst draws the navigation to system interfaces that implement queries or editions of objects related to the object source (Fig. 7). For example, starting from an invoice line list, the user can navigate to the client data. The set of possible destinations builds the arguments of this pattern. Once the arguments are built, the system task is in charge of carrying out the navigation.

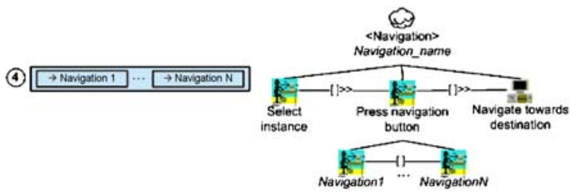


Fig. 7 Graphical primitive and structural task pattern for navigation

Display set. The display set primitive (Fig. 8) specifies the columns of the population instances that will be shown graphically. This primitive is a set of columns that the analyst can assign a name to. The names of the columns inserted in the sketch provide the values of the structural task pattern arguments.

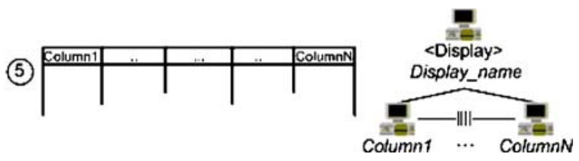


Fig. 8 Graphical primitive and structural task pattern for display set

Population. Once the correspondences between the structural task patterns and the third level of the presentation model patterns [23] are defined, the next step is to do the same with the second level of the presentation model patterns.

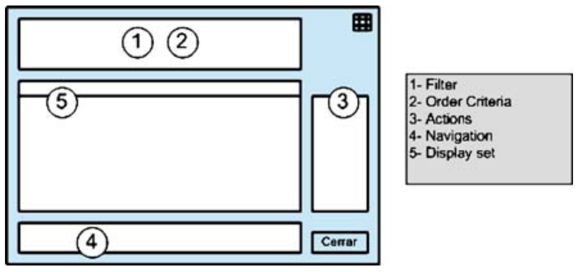


Fig. 9 Graphical primitive for population

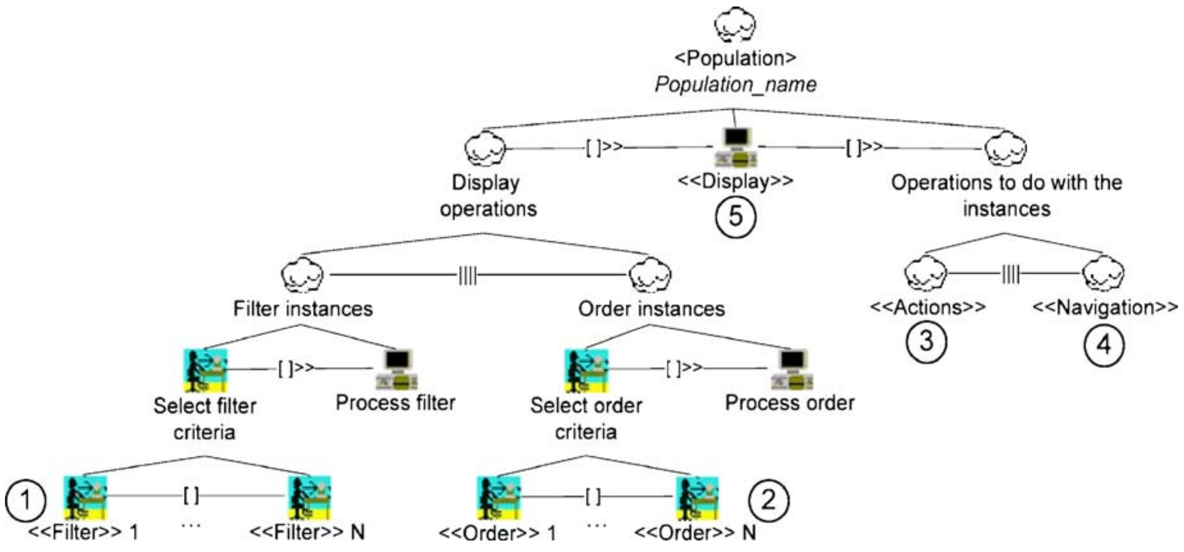
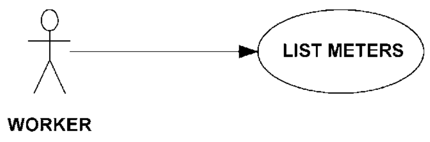


Fig. 10 Population with CTT notation

The population primitive presents to the user a list of instances from a business object class (i.e. a list of customers). As Fig. 9 shows, it may include all the primitives that represent elements of the third level in the OO-Method presentation model through structural task patterns. Figure 10 presents the corresponding structural task pattern. The numbers in circles show the common parts.

As Fig. 10 shows, the CTT that represents the population pattern includes interaction tasks that are in charge of filtering (*filter*) and arranging (*order*) the instances. The brackets represent grammatical-composition rules. In other words, they are points at which to hook the leaves to other structural task patterns. A system task is then used to show the instances of the objects (*display*), which are filtered and ordered by the selected criteria on the screen. Finally, the user can carry out *action* and *navigation* operations with these instances, which are represented in the diagram by means of abstract



USE CASE: LIST METERS
1. The user presses the menu option called "List Meters" ALTERNATIVE PATH ("ALL" FILTER) F.1 The user completes some of the filter variables: Customer, Model, Serial, Number, Zone, Calibre ALTERNATIVE PATH ("ZONE AND MODEL" FILTER) F.2 The user completes some of the filter variables: Zone, Model 2. The system shows the meters list ALTERNATIVE PATH (ORDER CRITERIA) O.1 The user selects the order criteria to order the meters by Serial Number and Code of the Zone (Ascending) 3. The user selects an instance ALTERNATIVE PATH (NAVIGATION) N1. The user selects a Navigation from among: Subscriber, Reading, Route order, History, Calibre ALTERNATIVE PATH (ACTION) A1. The user selects an Action from among: New Meter, Modify Meter, Delete Meter, Add reading, Last reading

Fig. 11 Use case model

tasks. All of these structural task patterns can be composed to model the interaction with a list of instances.

Case Study

This section shows the development process of a real system with the OO-Method methodology. This system is called AguasDeBullent, a water supply management system. In this case study, one of the possible routes across the MDA jigsaw puzzle is followed, using many of the models proposed by the OO-Method. The case study starts with the stage of requirements capture. First, the analyst creates the use case model. To keep the example simple, this paper focuses on one use case, *list meters*. This use case represents the functionality of showing a list with all the information about the water meters stored in the system.

Figure 11 shows the use case model with a template that specifies the steps required to accomplish the goal of this use case. Again, for the sake of simplicity, the template does not fully comply with the notation described in [11] but it does specify the use case in detail.

Once the functional requirements have been captured, the last step in requirements capture is to model interaction requirements using sketches (see Fig. 12).

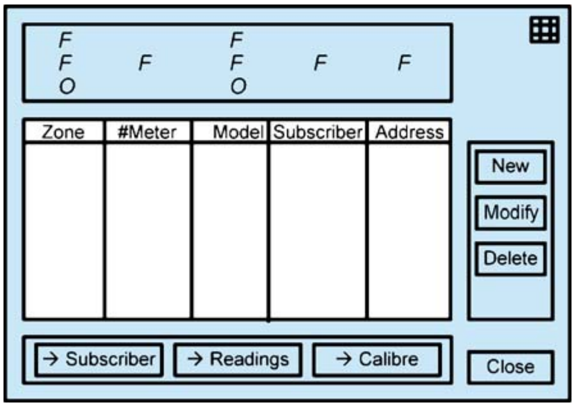


Fig. 12 Sketch

The CTT that represents the sketch is automatically built (see Fig. 13).

Some of the views that compose the conceptual model (object, functional and dynamic models) can be derived from functional requirements applying the transformation rules detailed in [11]. The presentation model can be derived from the CTTs by applying transformation rules explained in [12]. This case study focuses on the object model (Fig. 14a) and presentation model (Fig. 14b).

Finally, the model compiler automatically generates the source code of the fully functional

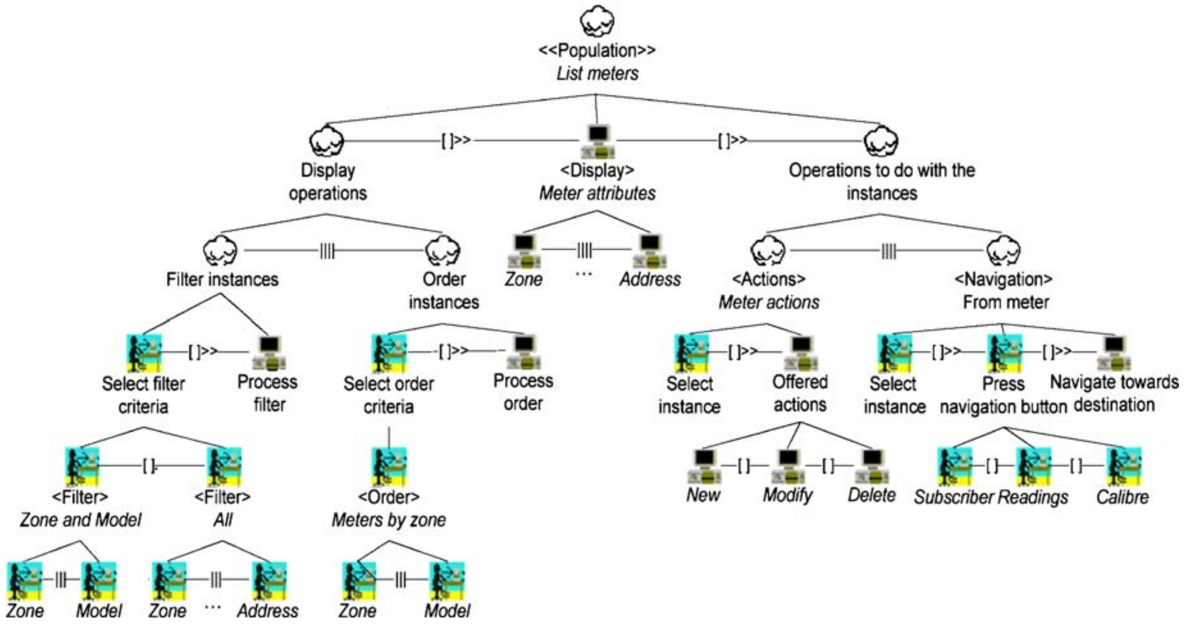


Fig. 13 CTT model

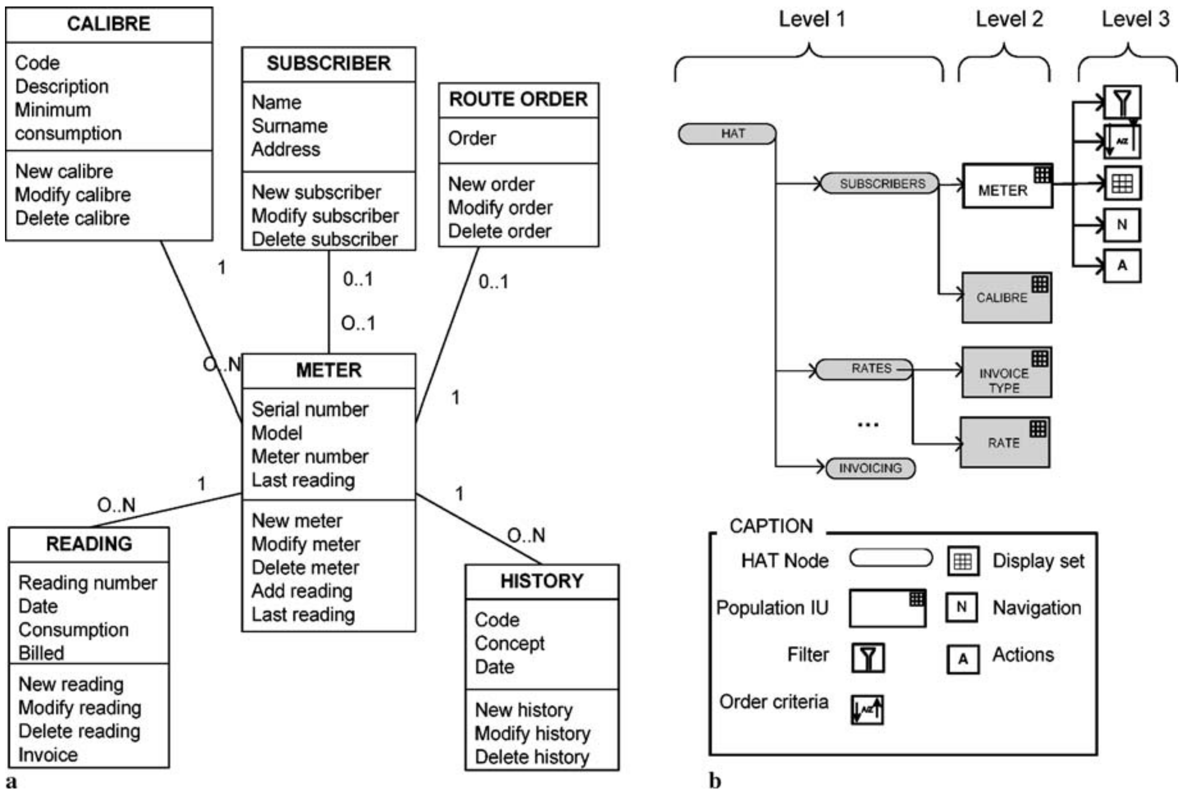
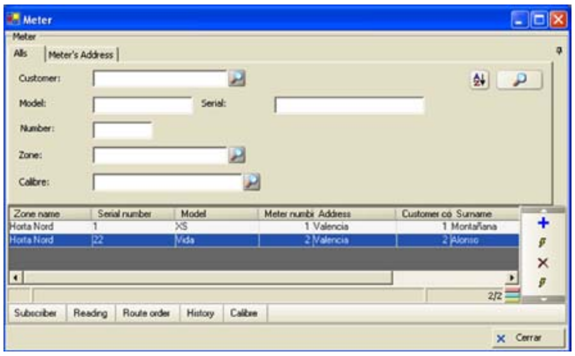


Fig. 14 (a) Object model. (b) Presentation model



Zone name	Serial number	Model	Meter numb	Address	Customer co	Surname
Horta Nord	1	XS	1	Valencia	1	Montañana
Horta Nord	22	Vida	2	Valencia	2	Alonso

Fig. 15 Final system

application. The generated window for the use case list meters is shown in Fig. 15.

Conclusions and Future Work

The MDA paradigm is modelled in four layers: CIM, PIM, PSM and code model. This paradigm is used in several software production methods that distinguish between the various abstraction levels with varying degrees of automation. In many cases, each MDA model is supported by a set of different models. Moreover, the specific models of each method can be built in a variable order, depending on a number of factors. These factors include: analyst's preferences, user's knowledge of computer systems, system size, and clarity of requirements. This fact, together with the large number of models proposed by the methods, results in a huge number of possible combinations for abstract modelling of the system. Independently of the chosen order, all the models must be coherent with the user's requirement and must represent a full system. This problem could be described as a jigsaw puzzle construction, with each model of the method representing a piece of the jigsaw that must be joined to other pieces for the whole to succeed.

This issue is discussed in this paper using the example of the OO-Method approach, a software production method based on the MDA paradigm. From among all the pieces of the OO-Method jigsaw puzzle, this paper focuses on those pieces designed to capture interaction requirements. The main reason for selecting these pieces is the fact that interaction modelling is often disregarded by the software engineering community. However, the human-computer interaction community has offered many successful techniques for capturing interaction requirements, a prime example are sketches. Sketches have been chosen to capture the interaction requirements in the OO-Method due to their simplicity. However, sketches cannot be used in an automatic transformation process unless we formalise their underlying language. We have chosen the ConcurTaskTree (CTT) notation to formally represent the sketches. CTTs allow the sketches to represent interaction unambiguously; they can be validated and then transformed into the OO-Method presentation model. The implementation of the tool to draw sketches and to synchronously generate CTTs is planned as future work. This functionality, together with the transformation of the task model into the presentation model, will offer efficient technological support for automatically generating application interfaces and will allow early feedback from the user. This provides an interesting and specific example of how to put together the various pieces needed to create a complete, MDA-compliant software production process, the so-called MDA jigsaw puzzle.

We also plan to assess the efficiency of the proposed interaction requirements technique, as well as the various alternatives for building the rest of the models. This will be done by means of empirical evaluation. Moreover, a case-base with the various methodological routes should be defined together with the factors that lead the analyst to choose one specific route.

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