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CNUIML: Towards the automatic generation of enterprise-level rich internet applications using controlled natural user interface modeling language

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Abstract. Model-based approaches attempt to facilitate the involvement of the end user (non-qualified user) in the software development process. Various approaches have been explored to automatically transform the user interface model into source code. However, the research community has focused less on describing the user interface with natural language. We used the Model Driven Architecture (MDA) approach and the Cameleon Reference Framework (CRF) to develop a Controlled Natural User Interface Modeling Language (CNUIML) for modeling the user interface of web applications. The meta-model of the designed language is represented by the meta-meta-model (class diagram), and the grammar of the language is developed using Extended Backus-Naur Form (EBNF). The usability of CNUIML has been evaluated through a case study. The models described with this language are AUI-level models based on CRF and a Platform-Independent Model (PIM) based on the MDA approach. In this study and evaluation, we have shown that the model designed with this language can be transformed into similar models such as task models or class diagrams using Model-to-Model (M2M) approaches. We have also discussed how the source code is obtained from the transformation of this model using Model-to-Text (M2T) methods.

1. Introduction

Since 1968, when the term "software crisis" was first used to describe the difficulties and problems caused by the complexity of producing useful and efficient software within acceptable timeframes and costs [1], the lack of or weak participation of end users in the software development process has been identified as one of the reasons for the failure of software projects [2].

For this reason, many efforts have been made in research and development to reduce waste and increase the success rate of software projects [3].

The research has shown that, according to one

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of the principles of Lean Thinking, minimizing the time span between initial problem understanding and presentation of a partial or final solution reduces resource waste and enhances project success [4]. In this regard, new software development methods emphasize the agility of the development process and rely on a set of basic principles and guidelines.

One approach considered in research literature to address the above challenge is to leverage the skills of experienced and capable users who are able to actively participate in the development process from its earliest stages and directly contribute to the development of the final result [5].

The research community seeks to determine whether providing a solution or developing a tool that helps end users participate in the development process can reduce the cost and time required to create useful software for organizations, particularly small businesses, and whether it helps solve crises caused by failed projects [5].

Model-Driven software Development (MDD) has been proposed in the research community to increase productivity and simplify the development process. This method aims to obtain the final product from initial models and their gradual transformation, which requires the use of automatic code generation technologies. The use of abstract models facilitates end-user involvement in the early stages of development, as these models allow end-users to focus on the most important concepts (abstractions) without being overwhelmed by numerous low-level details [6].

In many software projects, a significant amount of time is spent on user interface development (UI). Myers and Rosson have shown that creating a graphical user interface typically accounts for 48% of the source code, 45% of development time, 50% of implementation time, and 37% of maintenance time [7]. Consequently, 44% of the total time required to create an interactive system is spent developing the graphical user interface [6]. As end-user involvement in UI development increases participation in the overall development process [6], software project failures are reduced.

Model-driven development is supported by several artifacts, including tools, standards, and languages. Some of these artifacts are general MDD tools like AndroMDA [8], Acceleo [9], and ArcStyler. Others are specific to user interface development, such as the user interface definition languages UsiXML [10], UIML [11], XIML, the Interaction Flow Modeling Language (IFML) [12] adopted by the Object Management Group (OMG), and the Extensible Hypertext Markup Language (XHTML) adopted by the W3C (World Wide Web Consortium) [6].

Myers and Rosson classified these UI tools into three groups based on how the layout of the UI is specified and their dynamic behavior: language-based tools, interactive graphical specification tools, and Model-Based User Interface Development environments (MB-UIDEs) [7].

Language-based tools require developers to program in a specific language. Graphical and interactive feature description tools allow developers to design an interactive user interface. Finally, MB-UIDEs generate user interfaces based on models with different levels of abstraction (abstract, concrete, final interface), automatically or semi-automatically. They also provide tools for modeling and/or automatic generation of user interfaces. There are two main purposes for using MBUID: model reuse and automatic source code generation [13].

Model-based development has also influenced the development of web applications in recent decades. In this study, we investigated the development of rich Internet form-based web applications using user interface models. The user interface is a critical factor for the adoption of web applications [1].

The main topic of this research is the development of a modeling language that allows end users to define the required specifications for the user interface. This tool supports controlled natural language. Currently, modeling languages in the user interface domain are developed in two manners: based on the Unified Modeling Language (UML) and the UML profile, serving as a graphical language in a particular domain, and as a textual language in a specific domain [14].

The model-based approach proposed in this study starts with the description of the user interface in a textual modeling language based on the Model Driven Architecture (MDA) [15] approach and Cameleon Reference Framework (CRF).

MDA is a standard framework for software development defined by the OMG in 2001 for companies that need to rewrite their software to keep up with technological evolution. It provides an approach that allows interaction with the continuous growth of such technologies [16]. This approach has been the basis for the development of many user interface description languages [17–19].

MDA is based on three layers of models: Computation Independent Model (CIM), Platform Independent Model (PIM), and Platform Specific Model (PSM). Transformation between these models eventually leads to the creation of a model in a specific implementation, such as source code in a specific programming language (e.g., Java). A Domain-Specific Language (DSL) is used to write the specifications of MDA models, and the result is a meta-model that reflects the various features of the final software. The OMG has released Meta Object Facility (MOF) for this purpose.

A reference model, called CRF, which contains a set of models and metamodels, has been presented to provide different perspectives of the user interface, taking into account the diversity of user environments [20].

This reference model consists of four layers that are described and systematically transformed into each other. The first layer models a hierarchy (task & domain) of tasks that must be performed to achieve the user's goals. It also models the concepts critically related to the scope of these tasks [13].

In the next step, the user interface is modeled as Abstract Interactive Units or Objects (AIU/AIO) that are independent of the implementation (AUI). Then, a concrete model (CUI) of the user interface is represented by visible interactive units or objects (CIU/CIO). This model depends on the modality but is independent of the implementation and communication methods with the user and different communication technologies. This model is similar to the PSM model of MDA.

In the final layer, the user interface is represented in the form of source code based on the implementation technology (FUI) of the target programming language, such as Java, or markup language, such as HTML, etc. [13]. In the CRF modeling scenario, an AUI model serves as the PIM, and a CUI (or labeled CUI) serves as the PSM. FUI corresponds to PSI in the MDA method.

The use of natural language for this purpose is fraught with difficulties, as understanding natural language depends on the interpretation of both the author and the reader, which can lead to misunderstandings. The high flexibility of natural language allows developers and users to provide vastly different descriptions of the same problem. In contrast, formal languages are designed to address problems within a defined domain, relying on specific notations. However, these languages can be difficult for end users to learn due to their abstract nature. Controlled languages bridge the gap between natural language and formal language. Thus, they use a limited subset of the rules and vocabulary of natural language to overcome the problem of ambiguity and complexity of natural languages. Simplicity, a standard format for coherence and uniformity across all sentences, a short and active phonetic style, and a very limited vocabulary are the essential features of this type of language [21]. Therefore, the description of the user interface in this research is based on a controlled natural language optimized for describing the structure of the user interface and system data.

This controlled language is designed with the aim that in future research, the generation of source code, the structure of the system database and the relationships between entities, and the codes for updating and searching (CRUD) the data will be developed automatically from the description of the user interface using transformation languages.

Providing a controlled metalanguage close to natural language to describe user interface elements, with the possibility of grouping data elements in terms of entities, and automatic recognition of data types based on example values or descriptive expressions will be the result of this research.

The main contributions of this research are as follows:

- We have developed a controlled language based on natural language as a user interface modeling language;
- A meta-meta model is presented using UML for the language, based on IFML visual components;
- CNUIML is a context-free controlled language whose grammar is represented using Extended Backus-Naur Form (EBNF);
- CNUIML is designed so that the source code, database structure and its CRUD Operations are generated automatically;
- CNUIML recognizes data types based on sample values, automatically;
- The usability of the language has been evaluated using a case study;
- CNUIML has been developed based on the MDA approach and is compatible with CRF;
- This language can be implemented using common modeling tools. We have presented a proposal to implement the language using Xtext and Xtend for automatic generation of the editing environment and generator of the final code.

In the remainder of the paper, we provide an overview of the research community's efforts to create appropriate frameworks and tools for the development of model-driven user interfaces and their transformation into final code in Section 2. In Section 3, we present the methodology used in the research process, which is based on the model-driven development approach. Then, in Section 4, we describe Controlled Natural User Interface Modeling Language (CNUIML) and present the artifacts resulting from the solution design process. To evaluate the usability of CNUIML, in Section 5, we implement the user interface of an example system (case study) using the described language. In Section 6, we discuss the capabilities, shortcomings, and weaknesses of CNUIML, and in Section 7, we review the results of the research and conclude the achievements. Then we make suggestions for improving the current solution and strategies for developing and extending its capabilities.

2. Related works

As can be seen from the review articles, several languages have been invented and presented at different levels of abstraction [22,23].

Review studies on UIDLs began in 2003 [23] and expanded in subsequent years 2009 [24] and 2011, 2013 [25] by Jovanović et al., and [26] by Mayer and Rosson. The [27] by Mitrovic et al. is another review that compares model-based methods for describing the user interface of mobile software. In another study, Ruiz et al. [6] conducted an SLR on the results of 96 articles that introduced MBUIDs. Moldovan [22] also provided a list of 35 user interface description languages that were developed between 1999 and 2019. In 2023, Mejias et al. conducted an SMS to investigate various aspects of the research area [28]. The summary of their findings is as follows.

Research in the field of Model Driven User Interface Design (MDUID) has been popular since 2004. In [28], research conducted in this area was evaluated using the following classification scheme: process quality, product quality, proposed methodology, technologies supporting MDUID-based methods, models and metamodels, type of research and method, and application environment, in terms of academic or industrial settings.

From this review, it appears that the abstract model and the concrete model were of more interest to researchers compared to other models. Additionally, the vast majority of the methods were used in the academic environment. This research has shown that, although there is limited empirical evidence, MBUID methods improve productivity, reduce costs, and increase the efficiency and effectiveness of software production methods. They also significantly improve usability and performance. XML, EMF, and UML technologies have been more commonly used by researchers in this area than others [28].

The use of controlled natural language to extract and develop the user interface based on the requirements description is of interest in the research community. Juarez-Ramirez et al. proposed a method for extracting and determining user interface elements based on natural language descriptions of use cases in [29]. Pinto et al. [30] also presented an approach to automatically generate UIP from agile requirements specifications written in Concordia and its prototyping tool. This tool is capable of prototyping user interfaces for web-based applications. Dittmer and Jia [31] presented CABERNET, a Controlled Natural Language (CNL)-based approach to developing software code in natural language. With this method, programmers can use a language with a simple syntax based on a hierarchical outline to develop their desired software. A program written in the CABERNET language can be processed and executed in different environments using patterns.

Natural language-based methods have also been used for other products of the software development process, such as requirements documentation, test cases, and final code. However, most of these methods suffer from a common shortcoming. They were developed to help programmers increase their efficiency and thus save money and time. However, less attention has been paid to increasing end-user involvement and developing a tool that can be used to develop the program's user interface or final code with minimal programming knowledge and without lengthy training.

Research has shown that the methods presented also overcome some other shortcomings. Moldavan and colleagues have made a list of these shortcomings in their study [22]. Access to documented definitions of these methods is very limited in some cases, their integration with code generators is weak, the scope of automatic code generation for many of them is narrow and limited and does not include all common languages in the field of research, the expressive power of these languages is limited because they are abstract, their support is often limited to design time, they do not support runtime user interfaces, many of them are not integrated into the application architecture, they often lack efficient software support, such as IDEs, and they do not support multichannel user interfaces. In addition, many of them are very difficult for end users to use due to the high level of abstraction and require a slow learning curve.

In the next section, we will describe the step-by-step analysis, design, implementation, and evaluation of CNUIML based on MDA and Cameleon approaches.

3. Research method

This research aims to develop a DSL for describing form-based web app user interfaces that can be automatically transformed into source code. Mernik et al. [32] have presented models for the development of DSLs, based on which the DSL lifecycle includes 5 phases: decision making, analysis, design, implementation, and deployment. Visser [33] added a maintenance step to these phases.

In the first phase, the necessity of language development is examined, especially since the development of a specific language requires creating tools and documents, which poses a difficult decision from an economic point of view.

According to [32], two main concerns justify the development of a DSL: improving software economics and enabling software development by users with limited programming skills but reasonable familiarity with the application domain, or by end users with substantial familiarity with the application domain but virtually no programming skills. Facilitating the creation of a graphical user interface is one of the common patterns considered as a subset of the aforementioned concerns.

In the analysis phase, the problem domain is identified, and knowledge about the domain is gathered. Although many formal methods exist for conducting this step, it is often performed informally [32]. In this study, the analysis phase was performed by reviewing technical documentation, written knowledge of experts, previously developed specialized languages, and developed standards. Specifically, in this research, the resulting meta-model from the analysis relies on a simple mapping of the IFML standard.

In the design phase, extending an existing language is a common pattern, but in this study, we have developed a language that has little in common with the languages commonly used to describe user interfaces, so we used the invention pattern. When a DSL is designed using the invention pattern, a formal description is used rather than an informal one. There are many methods to describe the syntactic and semantic rules of a language. The most common approach for describing syntactic rules is through grammar-based systems. Hence, in this research, we use one of these formal methods to describe the syntax of the language (EBNF). This method is a suitable basis for language implementation by utilizing one of the most widely used tools in the research field (Xtext).

Common patterns in the implementation phase include solutions such as interpreters, translators, and preprocessors [32]. In future work, we will use the Model-to-Text (M2T) transformation approach, which is considered a subset of preprocessors. In this way, the DSL code is transformed into the source code of the target language (primary language such as HTML, CSS, or JavaScript). This step can be seen as equivalent to the PSI development step in the MDA approach using M2T methods.

The relationship between MDE and DSL engineering is becoming closer [34]. As suggested by Kurtev et al, MDE principles and tools can be seen as suitable support techniques for building DSL frameworks.

According to the definition given in [34], a DSL is a set of coordinated models. This includes a meta-model representing the abstract syntactic rules of the language, referred to as DDMM, concrete syntactic rules representing a concrete and visual form of the abstract concepts, and a semantic implementation resulting from transforming the concrete model into an implementable model. For example, in this research, we adopt a three-level structure of models comprising the meta-meta-model, meta-model, and model. In this abstract structure, we utilize the standard UML class diagram as a meta-meta-model to describe a meta-model representing the components of a user interface and their relationships - abstract syntax rules. We also introduce a textual language using EBNF [35], which will be converted to Xtext format in the implementation phase, corresponding to each of the abstract concepts as concrete syntactic rules.

The final user interface model, developed in the target language, will be a semantic implementation of this process.

Backus-Naur notation is a formal mathematical method used for describing a language. An improved and extended version of BNF, called EBNF, has been used to describe the syntax of many languages [36].

4. Controlled Natural User Interface Modeling Language (CNUIML)

In this study, a controlled metalanguage is developed that is close to natural language and can be used to describe user interface elements. Grouping of data items in the form of an entity, relationships between groups (entities), and automatic recognition of data types based on sample values or descriptive expressions are among the main features of this language.

Since context-free languages are the most widely used language types in computer science, this study has developed an innovative language that matches the characteristics of these language types.

We need a meta-meta-model to describe the user interface, which represents the main features of the user interface of a web application. Some of these features are defined by business analysts, software system designers, or programmers. Therefore, in the first step, we focus on some of the features that are related to the main requirements of the system and reflect the main concerns of the end user.

Most information systems (web applications) consist of a series of interconnected pages and forms through which users move and are directed from one page to another (navigation). Each page may contain one or more containers or sub-containers, each of which contains a set of related data items (form and sub-form). This structure forms a tree of objects, where each node is a form, a sub-container, or a data item. Each data item represents a single value or a set of values. These values are of the same type and can have a limited or unlimited range. Figure 1 shows the CNUIML meta-meta model for web application user interfaces.

According to the IFML standard, user interface components can be classified into four main groups: views and their components, events and operations, navigation and information flow, and grouping and modularization of the user interface.

In the first step, the end user focuses on the content of the views and the relationships between them and specifies the components of each view.

Ignoring the features related to navigation, events and actions, and notations related to modularization of the user interface, the standard meta-model is summarized in four features:

1. Form;

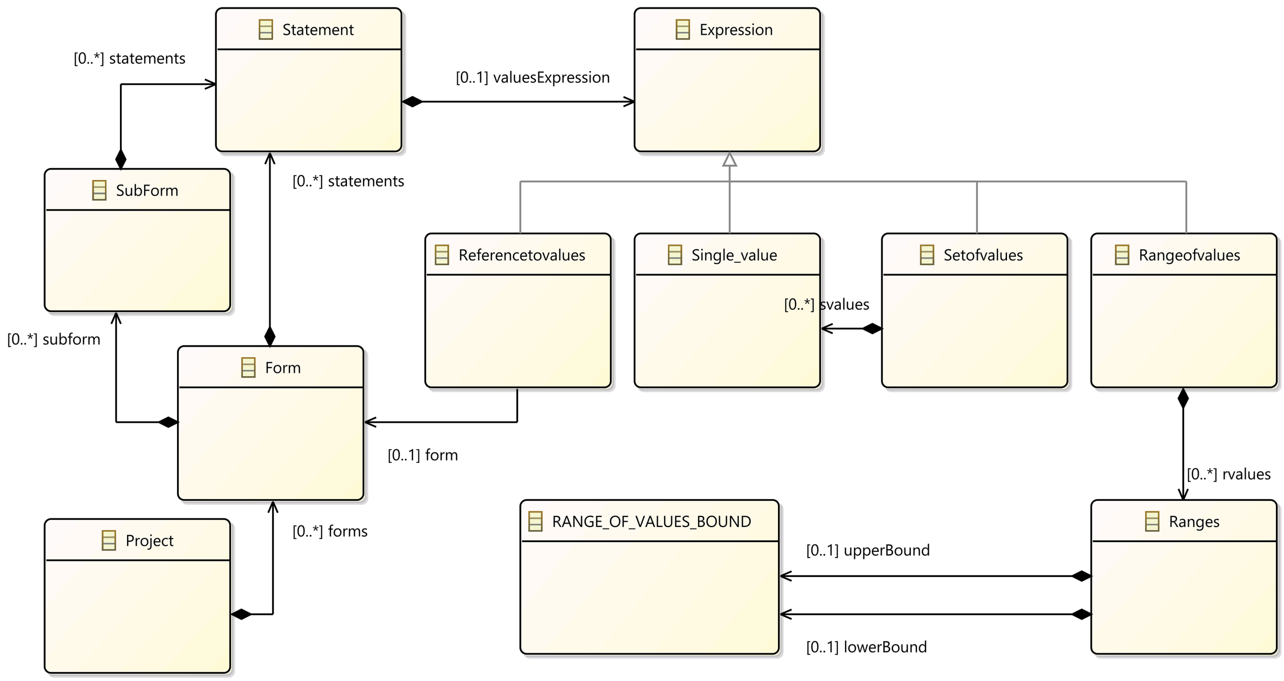


Figure 1. Language meta-model.

2. Sub-form (container or subspace);
3. Data item;
4. Domain range and type of values.

Figure 1, the CNUIML meta-model, shows that each web application is a set of forms that contain data items with a specific value type and domain. Each form can have zero or more associated sub-forms. The relationship between each form and its sub-form is assumed to be a one-to-many association.

The range and type of data values can be specified using a limited or unlimited set of specific data types or by referring to a specific data item in another form or a list of homogeneous data items.

Integer or decimal values, date and time, letters and character strings, logical values, email, and binary arrays (such as images and attachments) are acceptable data types of data items.

We need to design a textual language close to natural language so that the modularity of the project in terms of form and sub-form, components and relationships between data items, and the type and scope of each value can be accessed through it. In addition, the designed language must have common features in programming languages, especially syntactic grammar and unambiguous semantic description.

In this paper, we use context-free languages in EBNF form to describe language syntax. Context-free languages have enough power to describe recursive syntactic structures, so most programming languages use this type of grammar. The BNF form has been extended to EBNF with several modifications. The CNUIML meta-model is described using the EBNF method, as illustrated in Figure 2.

Every application is considered as a project that has an identifier or a name and includes a set of forms for displaying, entering, and editing data. This set of forms is a sequence of expressions that describe the forms and sub-forms related to them and ends with "End of Form". The project ID starts with a valid alphabetic character can include letters and numbers.

The description of the form begins with "Form of", continues with the descriptive ID of the form, and expands after "as". To describe the form, first, the descriptive expressions of the data items are given, then the description of the sub-forms is placed. The descriptive ID of the form of each statement includes valid letters, and spaces may be used between them.

To describe data items, two characteristics are required: the label or name of the data item and an example of its valid values that specify the type and range of values. The symbol "::" is used to separate these two parts.

The range of valid values of a data item can consist of one or more (a set) of individual values. Individual values may be limited or unlimited. For example, "Man" is a single value and "Man, Woman" is a finite set of values and "Bachelor, MA, PhD, ..." is an unlimited set of values. Date, time, numbers, literal strings, email, logical values, and binary values are allowed values. Binary values refer to images or other attachments that can be loaded in binary form.

To describe the range of values of an expression,

```
project = ”Project” , whitespace , identifier , whitespace
, { form definition } ;

identifier = alphabetic character , { alphabetic character
| digit } ;
whitespace = ? white space characters ? ;

form definition = ”Form of” , title of form , ”as” ,
whitespace , statement  , whitespace , { statement  ,
whitespace } , { subform definition } ”End” ”Of” ”Form” ;

title of form = word , { whitespace , word } ;

subform definition = label ,  ”List from” , title of form ,
 ”as” ,  whitespace , statement , whitespace , { statement
, whitespace } ;

statement = label  , ”::” ,  expression ;


expression =
single value
| (single value ,  ”,” , {single value ,  ”,” } , single
value [”,...”])
| (range of values , {”,” range of values})
| (”a” | ”an”) , label , ”in” , title of form ”List”;

label =  word , { whitespace , word } ;
word =  alphabetic character | digit , { alphabetic
character | digit } ;


range of values =  range of values bound , ”..” , range of
values bound , { range of values bound , ”..” , range of
values bound } ;


range of values bound = ( date | time | number ) ;


single value = ( date | time | number | email | logical |
string | binary ) ;

string = ”[[” , { all characters − (”[[” | ”]]”)}, ”]]” ;
date = year , ”–” , month , ”–” , day ;
year = ( ”19” | ”20” ) , digit , digit ;
month =  ( ”0” , digit − ”0” ) | ( ”1” , ”0” | ”1” | ”2” )
;
day = ( ”0” , digit − ”0” ) | ( ”1” | ”2” , digit ) | ( ”3”
 , ”0” | ”1” ) ;
time = hours , ”:” , minutes , ”:” , seconds ; (* ISO 8601
*)
hours = ( ”0” | ”1” , digit ) | ( ”2” , ”0” | ”1” | ”2” | ”
3” ) ;
minutes  = ”0” | ”1” | ”2” | ”3” | ”4” | ”5” , digit  ;
```

Figure 2. CNUIML grammar.

```
seconds  = ”0” | ”1” | ”2” | ”3” | ”4” | ”5” , digit  ;
number = [  ”+” | ”–” ] , digit , { digit } , [ ”.”  ,
digit  , { digit } ] ;

email = alphabetic character | digit , { alphabetic
character | digit} , [ ”.” , alphabetic character | digit ,
{ alphabetic character | digit} ] , ”@” , alphabetic
character | digit , [{ alphabetic character | digit | ”–” }
, alphabetic character | digit ] , ”.” , {alphabetic
character | digit , [{ alphabetic character | digit | ”–” }
, alphabetic character | digit ] , ”.”} , ,  alphabetic
character | digit ,  [ alphabetic character | digit | ”–” ,
{ alphabetic character | digit | ”–” } , alphabetic
character | digit ] ;

logical = ”yes” | ”no” | ”true” | ”false” ;
binary = ”Attachment” | ”Image” ;
```

Figure 2. CNUIML grammar (continued).

we use one or more ranges of values that are shown as “start..end”, where “start” is the minimum value and “end” is the maximum value of the range. Date, time, and numbers are valid values for the beginning and end of the range.

In some cases, the range of valid values of a data item is limited to the set of values available in other entities of the project. Referential expressions are used to describe this type of range which refers to the name or label of a data item from another form of the project.

The definition of sub-forms is the same as that of the form, encompassing the title of the sub- form and the title of the referenced form. Each sub-form has a one-to-many association with the main form. The titles of the data elements within the sub-form may either be a selection from the titles of the data items in the referenced form or encompass all of them. The same descriptive expressions are used in the description of the data elements of the sub-forms as in the description of the forms.

5. Case study

In this article, we use a case study to evaluate the usability of the designed DSL. The subject of this case study is a course registration system provided by teachers and lecturers. The purpose of this course management system is to record details for each instructor, course subject, and training course.

The necessary forms of this system, which include profile registration, instructor education and experience, course subjects, course registration, and student profiles, are presented graphically. These types of forms are available to end users as printed/online forms. Figure 3 shows the class diagram of the system.

Figure 4 shows the course registration form. In this form, in addition to the set of data items of this entity, the course sessions sub-form is also shown, and it shows that the course sessions entity has an association with the course entity. Also, the range of values of two data items (subject and teacher name) is limited to the set of values of entities obtained from other forms. This relationship is considered as referential dependency in the next step. Figure 5 shows the description of the course registration form. Each of the data items is named descriptively, and the range of its valid values is specified with an example. Reference expressions are used to specify the range of “Subject” and “Teacher Name” values. At the end of the form description, there is also a description of the session sub-form. This sub-form also contains data items with specific values.

Figure 6 shows the set of data items of the student entity in a form. Also, the data items of the contact entity and its association with the student entity have been specified. The sub-form of registered courses also references data items extracted from the course entity, which shows the association between the student entity and the course. Figure 7 shows the set of the teacher’s entity data items. The contact sub-form also shows the contact entity data items, which has an association with the teacher entity.

6. Discussion

In this section, we discuss the alignment of CNUIML with the Cameleon reference model and the MDA approach. Most MBUID approaches are based on the CRF [6]. MDA is a standard framework for software development originally described by the OMG in 2001. Three levels of models are defined in MDA: CIM, PIM, and PSM. The CRF reference model layers correspond to the models introduced in MDA. The

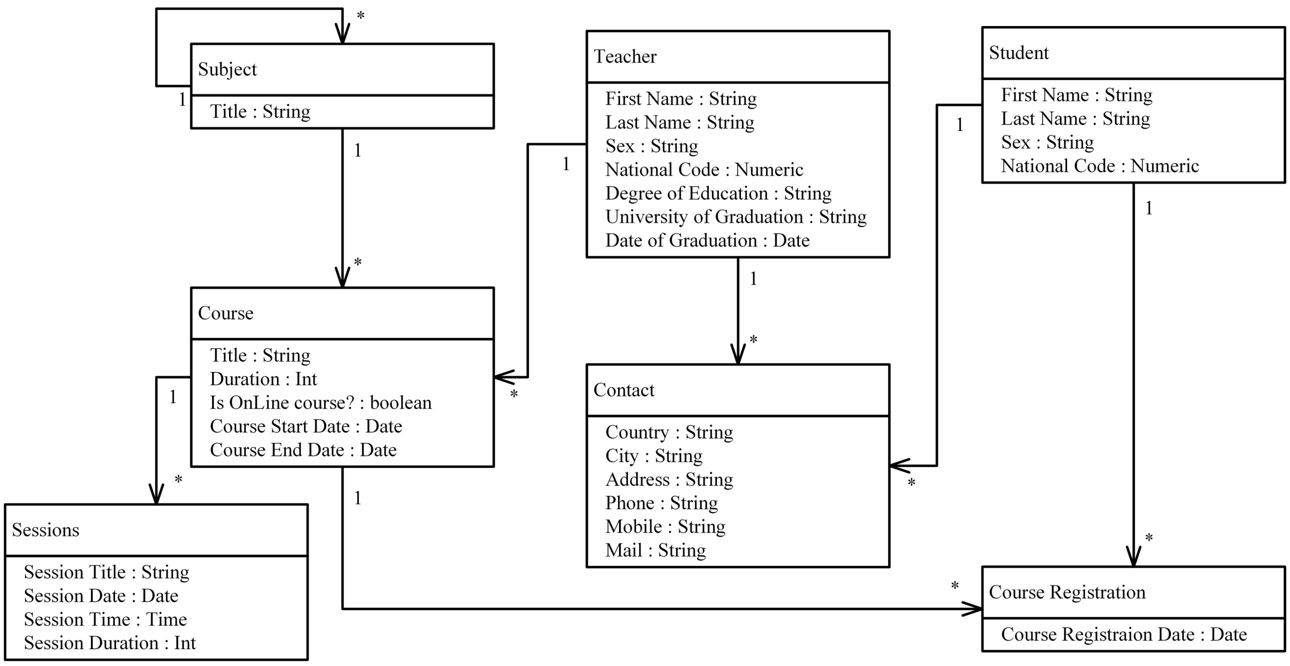
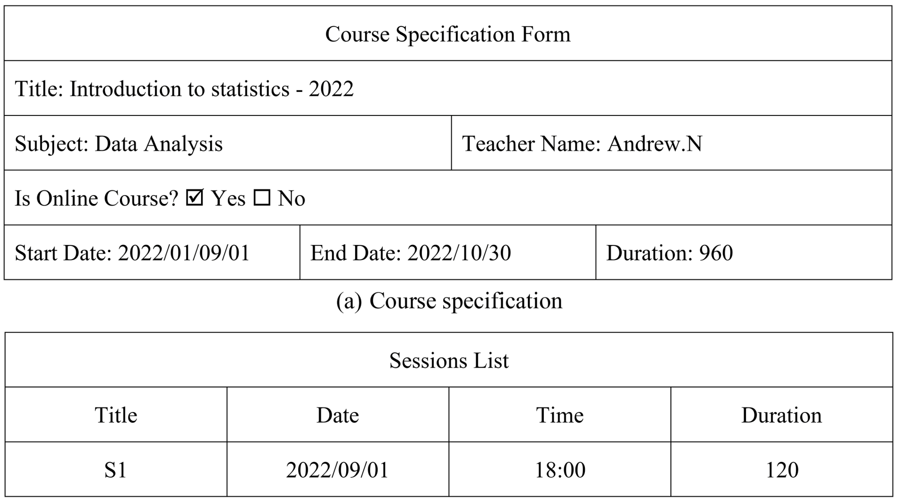


Figure 3. Course management system class diagram.



Course Specification Form		
Title: Introduction to statistics - 2022		
Subject: Data Analysis	Teacher Name: Andrew.N	
Is Online Course? ☑ Yes ☐ No		
Start Date: 2022/01/09/01	End Date: 2022/10/30	Duration: 960

(a) Course specification

Sessions List			
Title	Date	Time	Duration
S1	2022/09/01	18:00	120

(b) Course sessions

Figure 4. Course registration form.

model of tasks and concepts in CRF can be considered as corresponding to the level of CIM or PIM. AUI is considered a PIM from the MDA perspective, and CUI is considered a PSM because it depends on a specific modality, but its implementation is independent of any technology. Finally, the FUI model, which implements the user interface based on source code and depends on a specific technology, is considered as a PSI model.

The CNUIML model refers to the tasks and concepts of the system and is computation independent. Although the task hierarchy and navigation are not included in the current version of the language, they can be implemented in the future with some modifications. Since the language has no modality and is platform independent, it can be considered as PIM. This language is at the abstraction level of AUI, from the CRF point of view. It is an abstract language because the input and output data are the basis of the model, not the operations associated with them.

The task model plays an important role in the design, development, and analysis of interactive systems [37]. Task analysis is the infrastructure of user-centered design approaches and aims to collect information from users about what they do and how they do

```
Form of Course Specification as
  Tile :: [[an introduction to statistics-2022]]
  Subject :: a Title in Subject Specification list
  Duration :: 5..10000
  Teacher Name :: a Name in Teacher Specification List
  is Online Course :: Yes,No
  Course Start Date :: 2022-09-01
  Course End_Date :: 2022-10-30

  Sessions List From Session Specification as
    Session Tile::S1
    Session Date ::2022-09-01
    Session Time ::00:00..23:59
    Session Duration ::5..300

End of Form
```

Figure 5. Course specification and sessions.

```
Form of Student Specification as

  First Name :: Andrew
  Last Name :: N
  Birth Date :: 1970-12-28
  Sex :: Male,Female
  National Code :: 20900000000

  Contact List From Contact Specification as
    Country :: US,England,China,...
    City :: New York,London,...
    Address :: [[No 123,Some St,Any Ave]]
    Phone::+11233152240
    Mobile::+13256521412
    Mail::A@y.com

  Course Registration List From Course Registration
    Specification as
    Course Title :: a Title in Course Specification List
    Course Registration Date :: 2022-08-28

End of Form
```

Figure 6. Student profile form.

it [38]. Currently, there are several methods, notations, and tools for task modeling and analysis, typically featuring a comprehensive notation to support different task types and functions, hierarchical decomposition, and support for integration through device modeling and dialogs. The most commonly referenced notations are CTT and Hamsters. Comparing these two notations with others over a twenty-year period, it is clear that CTT is the dominant approach in the general trend, with the exception of 2013. See [38] for a list of the major task modeling methods.

In the tasks and concepts layer, the task model can be transformed into the AUI model based on the CNUIML method using one of the Model-to-Model (M2M) transformation paradigms widely used in research literature. The M2M transformation paradigm follows the descriptive programming paradigm (e.g., ATL (Eclipse Foundation, 2016b)) or QVT. How these

```
Form of Teacher Specification as
   First Name ::Andrew
   Last Name ::N
   Birth date ::1970-12-28
   Sex ::Male,Female
   National Code ::2090000000
   Degree_of_Education ::BA,BS,BFA,MA,MS,MD,MFA,MBA,PhD,PharmD,
     JD,SJD,Post-doctoral
   University_of_Education ::MIT
   Graducation Date ::2022-02-09

   Contact List From Contact Specification as
      Country :: US,England,China,...
      City :: New York,London,...
      Address :: [[No 123,Some St,Any Ave]]
      Phone::+11233152240
      Mobile::+13256521412
      Mail::A@y.com

   Courses List From Course Specification as
      Title :: [[an intruduction to statistics -2022]]
      Subject :: a Title in Subject Specification list
      Duration :: 5..10000
      Course Start Date :: 2022-09-01
End of Form
```

Figure 7. Teacher registration form.

transfer languages can be used to extract the CNUIML model from the task model is beyond the scope of this article. The authors intend to investigate this issue in a future study.

Extraction of the domain model from the user interface or its model has also been explored in the community [39]. The user interface elements are also mapped to classes and relationships between them in the proposed approach, using the M2M transform method. Each form in CNUIML corresponds to a group of related data, which is considered as a class of entities. The relationships between forms are also mapped to the relationships between classes and entities. The data values and their types are also mapped to the attributes of each class.

Analysis and inference of the existence of relationships between classes are possible through the use of referential dependency and the definition of sub-forms. A one-to-many relationship between two forms exists when the value of a data element has a referential dependency on the data values of another form. If form f_1 contains data element d_1, whose values are constrained to the values of element d_2 of form f_2, it can be inferred that a one-to-many relationship exists between form f_1 and form f_2. This fact can be similarly inferred if there is a sub-form f_2 in the definition of form f_1. If a one-to-many relationship is derived between f_1 and f_2 and vice versa, it can be concluded that there is a many-to-many relationship between these two forms.

In the model-driven development process, as well as in the CRF reference model, the transformation from the initial model into the final model (source code) is performed using the M2M and M2T transformation languages. The CNUIML model can also be transformed into lower-layer models (CUI and FUI) by using reification and translation. A suitable tool for implementing transformations from AUI to FUI is Xpand. The Xpand language, developed within the scope of the Eclipse Modeling Framework (EMF), uses patterns that contain definitions of how transformations are performed. Using this tool to implement the transformation process is one of the authors' future works.

7. Conclusion and future works

We have addressed the issue of cost and time reduction during the software development process. Software development is a continuous and incremental process, in which a product or output is developed at each step. This process continues from the initial artifacts, a form of requirements described by the end user, to the final product created through the transformation of intermediate artifacts. Transforming products and repeating steps usually wastes time and resources. Various stakeholders and human factors are involved in each of the development steps. Additionally, a lack of common understanding of the problem and solution among stakeholders contributes to time and resource wastage.

In research literature, one of the main strategies to reduce waste is the use of a model or formal language to develop intermediate products and automate the transformation of artifacts until the final product, i.e., program code, is achieved. This approach has led to the emergence of model-based software engineering. In the development of web-based applications, the trend in the research community is also towards model-based web engineering. In this approach, the development process is based on the development of appropriate models based on the requirements and continuous and repeated transformation of the models until the final code is achieved. On the other hand, the development of the user interface consumes most of the time in the software development process. Therefore, in this research community, special attention has been given to software development based on the design of the user interface.

In this research, we have developed a controlled language based on natural language for the initial description of functional requirements by the end user, which allows describing the user interface of form-based web applications. The structure of a form-based web application includes several related forms for processing and displaying information. Each form contains data elements of a specific type and also shows the relationship between the main form and its associated sub-forms. It is a context-free controlled language described by Extended Backus-Naur Form (EBNF). A case study was also used to evaluate the usability of the language.

The Controlled Natural User Interface Modeling Language (CNUIML) language is designed to be enriched by adding descriptions related to steps such as business analysis and solution design. Finally, by transforming the initial model into the final code, one obtains a program in common source languages such as JavaScript, HTML5, and CSS. The data model and relational database structure can also be extracted from the transformation of the initial model.

Although efforts have been made to consider all end-user requirements in describing the initial user interface of the application, with a focus on the most important concerns - namely, the structure and content of the forms and the relationships between the main forms and sub-forms - some less important concerns, such as the users allowed to interact with the forms based on their role and the life cycle of forms and sub-forms, have been ignored in this language. The authors of this paper will address these issues by extending the language in future developments.

Another future work is to develop a visual and responsive tool that converts a descriptive expression based on the CNUIML meta-language into a visual model of the user interface.

Extending the language to support business analysis, navigation, advanced user interactions, events, operations related to user interactions, access control, and advanced data modeling are also future work under this research. Other future goals include the extraction of model-to-code transformation patterns and the development of a tool based on Xpand technology that transforms the forms specified by the CNUIML language into the codes required to build a database and web application based on the MVC-MC or MVVM architecture. Additionally, generating transformation rules in the ATL or QVT language to extract equivalent models such as Interaction Flow Modeling Language (IFML) or abstract models such as Unified Modeling Language (UML) class diagrams and task models is also a future research topic. Another research topic is database code extraction and related CRUD operations.

We have attempted to validate the usability of the CNUIML model through a case study. However, evaluating this model based on conventional evaluation indicators and methods presented in research literature is a separate investigation. Ruiz et al. presented a framework of 21 criteria for evaluating model-based user interface design methods in [6]. Mejias et al. [28] have also proposed the evaluation of some qualitative characteristics of the software development process as well as the software product on which MDUID-based approaches are effective.

Finally, researching, inventing, or improving methods that can extract the CNUIML model from existing source code may be one of the topics of future research.

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