Automated Enterprise Applications Generation from Requirement Model

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Abstract—Notwithstanding the advancement of software engineering for enterprise applications, the process of software implementation is still time-consumming and error-prone. This situation is more severe when developing the custom software, because the requirements are always changing during the whole development processes. This issue could be alleviated by reusing exiting code or services in the private and public repositories. Nevertheless, the reuse could fail if no existing service is matched or existing services could not be composited to satisfy the requirements. Eventually, the developers have to implement the business logic manually for the un-satisfied requirements. In this paper, we present an approach which can automated generate business logic from requirement model for enterprise applications. Unlike other works, our approach does not need to specify design model such as sequence diagram, the business logic could be directly generated from operation contracts of requirement model. Operation contracts only contain the preconditions before executing the action, and the postconditions after execution. Moreover, the generated off-the-shelf code is adopted the same multi-layer structure as Java EE and .NET platforms which are robust, scalable, and widely used in enterprise application developments. Finally, a case study of library management system demonstrates the feasibility and efficiency of the proposed approach in our implemented RMCode tool.

Keywords—code generation; enterprise applications; requirement model

I. INTRODUCTION

Enterprise applications are about the display, manipulation, and storage of large amount of often complex data and the support or automation of business processes with that data [1]. Enterprise applications face the challenges in leverage the speed, security, scalable and reliability. That is the reason why the development platforms such as Java EE and .NET are widely adopted in enterprise application developments, which can provide a powerful set of APIs to shorten development time, reduce application complexity, and improve application performance. Although the platforms have already taken charge most complexity, developers still need to implement business logic manually. For example, when developer implements the business logic about borrowBook in Java EE platform[2], the code should like this:

```java
@PersistenceContext
EntityManager em;

public Boolean borrowBook(int uid, int barcode) {
    User user = em.find(User.class, uid);
    BookCopy copy = em.find(BookCopy.class, barcode);
    Loan loan = new Loan();
    loan.setLoanedUser(user);
    loan.setLoanedCopy(copy);
    user.setLoanedNumber(user.getLoanedNumber() + 1);
    user.addLoanedBook(loan);
    copy.addLoanedRecord(loan);
    copy.setStatus(CopyStatus.LOANED);
    em.persist(loan);
    em.merge(copy);
    em.merge(user);
    return true;
}
```

For the design patterns of inversion of control[1] and dependency injection[2] first coined by Martin Fowler, entity manager of JPA (persistence layer in Java EE) takes charge of object responsibilities about finding(em.find), adding(em.persist), updating(em.merge), and deleting (em.remove). And entity manager could also be automatically injected into session beans (business layer in Java EE). The main task for developer is to use entity manager APIs to implement business logic. For the business logic of borrowBook above, the first step is to find the User and BookCopy instances through the input variables uid and barcode. The second step is to create a new instance Loan, set references among user, copy, and loan, update loaned number of this user, and set loaned status of this copy. The last step is to persist the corresponding objects loan, user, and copy to database.

As we known, the coding the above business logic is tedious, time-consuming and error-prone. For the project without complex business logic, developers may directly write code without explicitly making a design first. Otherwise, the design model should be presented first according requirement model, e.g sequence diagram, then developers write code according that design model. In order to improve this situation, [3] proposed sequence integration graph (SIG), which acts as an intermediate to help automatically generate business logic from sequence diagram. However, the experimental result shows that only less than 48% correct source code can be generated. MasterCraft [4] could generate enterprise applications from application layer model, user interaction model and database

[1] http://martinfowler.com/bliki/InversionOfControl.html
[2] http://martinfowler.com/articles/injection.html
Different modules in the business layer. In specification phase, behaviours are precisely defined in each operation contract. Furthermore, those phases could be iterated in any epoch, and requirement could be immediately validated by generated code.

The remainder of this paper is organised as follows: Section 2 overviews of our approach. Section 3 defines business logic generation from operation contract. Section 4 presents enterprise applications generation from requirement model, and then Section 5 provides the demonstration and performance analysis by the case study of library management system. Section 6 discusses the limitation related to RQ2. Section 7 discusses the related work, and finally, Section 8 concludes this paper and outlines the future work.

II. Overview

RQ1 refers to the overview of proposed approach, which is presented in Fig.1. Business and persistence layers of enterprise applications could be automatically generated from requirement model, which contains use case diagram, conceptual class diagram, and operation contracts. The generated code could also validate the requirement model. Fig.1 involves the following three questions:

1. **Why do we choose layered architecture like Java EE and .NET platform for enterprise application generation?**

   [AndroMDA](http://andromda.sourceforge.net) shows layered architecture pattern is a solid general-purpose pattern, and usually a natural choice for enterprise application developments. Under the principle of separation of concerns, the responsibilities are separated into different isolation layers, and the number of layers depends on the complexity of target problem. The layered pattern makes high cohesion inside layer, low coupling between layers. This conforms general responsibility assignment software principles (GRASP) which consist of guidelines for assigning responsibility to classes and objects in object-oriented design. And isolation of layers makes coupling even lower by supporting indirection pattern of GRASP. For example, a request of object changing from the presentation layer must first go through the business layer and then to the persistence layer. In addition, there are many mature platforms supporting this layered architecture pattern such as Java EE and .NET platforms. In those platforms, controller and pure fabrication patterns of GRASP is implemented in such EJB manage bean of Java EE for taking responsible for receiving or handling a event.
from presentation layer. Furthermore, as the creator pattern of GRASP and factory pattern of GoF [7], entity manager take creating objects responsibility in the persistence layer. By the concept of inversion of control, instead of an entity object looking up, or deleting other entity object, entity manager take the those responsibilities into a charge. And all the dependencies such as the reference to entity manager could be automatically injected to other components in the same layer and the upper business layer by the implemented dependency injection pattern. Under the principles of GRASP, separation of concerns, design patterns of GoF, inversion of control, and dependency injection, layered architecture could make enterprise applications high cohesion and low coupling, easy to implement, test, and maintain. From all above reasons, we choose layered architecture like Java EE and .NET platforms for enterprise application generation.

2. What is in the requirement model? This answer depends on what is generated from the requirement model. In Fig. 1 layered enterprise application is generated from the requirement model. The business logic in business layer can be retrieved after analysing the actors and use cases involved in the target problem. Therefore, use case diagram is included first in the requirement model. The business logic operates domain model to fulfill the business target. The domain model are implemented as entity classes in the persistence layer, which can be specified by conceptual class diagram in the requirement model. In our approach, we does not include any design model such as sequence diagram to specific business logic. However, the details description of system behaviour (business logic) are required to be specified in requirement model to generate code. Referring to the use-case model within RUP, operation contract can precisely specify the system behaviour, the precondition of operation contract describes the system state before the executing this operation, the postcondition contract describe the state changes to objects in the domain model after this operation has executed. What is in the contract is the same description in the business logic for domain model. Therefore, the proposed approach contains use case diagram, conceptual class diagram and operation contracts in the requirement model.

3. How does the requirement model translate to code? According to the answer above, persistence layer of enterprise applications could be seamlessly generated: the conceptual class diagram can be directly translated to entity classes in persistence layer, and an entity manager is required to manage lifecycle of entity class. The main generation task for business layer is how to translate operation contracts to business logic, which invokes persistence layer APIs to operates domain model. The details of translation will be discussed later.

In the following sections, we analysed the business logic written in such as Java EE, summarised the code pattern of business logic. Then after comparing to the operation contracts, we will show how this contract translate to business logic.

III. OPERATION CONTRACT TO BUSINESS LOGIC

A. Analysing BorrowBook

In order to find code pattern in business logic, borrowBook written in Java EE is presented in Fig. 2 with operation contract.

As showed in the marked points, the instance em of entity manager is automated injected into business layer. Usually, entity manager is used to find objects (user and copy instances) first. After that, new objects (loan instance) may be created. If new objects is created, the references between new objects (loan instance) and exiting objects (user and copy instances) are required to be set. Then, the state of objects may be updated. If persistence is required, the new objects and changed objects should be persisted into database or other storage. Therefore, the main pattern of business logic is to find the existing objects, create the required new objects, set references and update state of objects.

The corresponding operation contract is in the right side of Fig. 2. All atomic actions of business logic have the corresponding representations in object constraint language (OCL) http://www.omg.org/spec/OCL/. OCL is a standard contract description language in UML, and it is faultless, less mathematical background required and widely used in industry, e.g. IBM product line and the projects of the foundation of Eclipse. In the case of borrowBook, finding object is specified as an iteration operation (any) of OCL, e.g, all the instances of entity User has an instance its UserID is equal to input variable uid. Creating object is a standard operation oclIsNew() of OCL. Setting one-to-one reference is described as basic equal operation of OCL, e.g, the reference LoanedUser of instance loan is the instance user. Setting one-to-many reference is described as standard operations include, includeAll, exclude, and excludeAll of OCL, e.g, the references LoanedBook of instance user include the instance loan. Updating action is same as setting one-to-one reference but it could use previous state to describe present state, e.g. the number of loaned book plus 1 after borrowBook executed.

From the analysis, the relations between operation contract and business logic is clear, the business logic could be generated from operation contract. The details translation rules are presented in next sub section.

B. Translation Rules

OCL is abundant in grammatically mechanism to describe system state. In our case, OCL only need to describe the state for business logic in enterprise applications. After analysing the business logic, the business logic contains atomic actions such as finding object, setting reference, creating and delete object, and updating object. That conforms the well known CRUD (create,read,update, and delete) operations. The details of atomic actions and corresponding contracts are listed in Tab. 1. There are 15 atomic actions, the taxonomy is based
**Operation Contract in OCL**

```java
public Boolean borrowBook(int uid, int barcode) {

    User user = em.find(User.class, uid);
    BookCopy copy = em.find(BookCopy.class, barcode);

    Loan loan = new Loan();
    loan.setLoanedCopy(copy);
    loan.setLoanedUser(user);
    loan.setLoanedNumber(user.getLoanedNumber() + 1);
    copy.addLoanedRecord(loan);
    user.setLoanedNumber(user.getLoanedNumber() + 1);
    copy.setStatus(CopyStatus::LOANED);
    em.persist(loan);
    em.merge(copy);
    return true;
}
```

**TABLE I: Translation Rules**

| CRUD | ReturnType | Atomic Action                                                                                      | OCL                                                                 |
|------|------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Create | ob:Classifier | createObject(Classifier)                                                                 | Pre: Classifier.allInstances()→exclude(ob)                         |
|      | Boolean    | addOneToManyAssociation(ob:Classifier, asso:Attribute, addOb:Classifier)                       | Post: ob.asso∈addOb                                                |
|      | Boolean    | addOneToOneAssociation(ob:Classifier, asso:Attribute, addOb:Classifier)                      | Post: ob.asso = addOb                                             |
| Read  | ob:Classifier | findObject(Classifier, obAttribute:Attribute, op::Operators, value:PrimeType)                  | ob:Classifier=Classifier.allInstances()→any(o:ob.obAttribute op value) |
|      | ob: Set(Classifier) | findObjects(Classifier, obAttribute:Attribute, op::Operators, value:PrimeType)                | o.asso                                                            |
|      | ob:Classifier | findAssociationObject(ob:Classifier, asso:Attribute)                                          | o.asso                                                            |
|      | ob: Set(Classifier) | findAssociationObjects(ob:Classifier, asso:Attribute)                                         | o.asso                                                            |
| Read  | Boolean    | standardOperationsObject(ob:Classifier, stanop::StandardOperation)                           | ob.stanop                                                         |
|      | Boolean    | standardOperationsObject(ob: Set(Classifier), stanop::StandardCollectionOperator)            | o.asso.stanop                                                    |
|      | Boolean    | checkAttributeState(ob:Classifier, attri:Attribute, op::Operators, value:PrimeType)           | Pre: ob.attri op value                                           |
|      | Boolean    | checkObjectState(ob:Classifier, stanop::StandardOperation, op::Operators, value:PrimeType)    | Pre: o.assop op value                                           |
| Read  | Boolean    | updateObject(ob:Classifier, attri:Attribute, op::Operators, value:PrimeType)                 | Pre: ob.attri = ob.attri@pre op value                             |
|      | Boolean    | updateObjectWithNew(ob:Classifier, attri:Attribute, value:PrimeType)                         | Post: ob.attri = value                                           |
| Delete | Boolean    | releaseObject(ob:Classifier)                                                                 | Pre: Classifier.allInstances()→exclude(ob)                         |
|      | Boolean    | removeOneToManyAssociation(ob:Classifier, asso:Attribute, removeOb:Classifier)                | Pre: ob.assop→exclude(removeOb)                                    |
|      | Boolean    | removeOneToOneAssociation(ob:Classifier, asso:Attribute, removeOb:Classifier)                | Pre: ob.assop.oclIsUndefined() = true                            |

**Fig. 2: borrowBook in Java EE and Operation Contract**

on CRUD. For the taxonomy of `create`, atomic actions contain `createObject`, `addOneToManyAssociation`, `addOneToOneAssociation`. Atomic action `createObject` is generated when precondition specifies that object `ob` is excluded in all the instances of `Classifier`, and postcondition specifies that object `ob` is new object and included in all the instances of `Classifier`. The association has two situations, atomic action `addOneToManyAssociation` is generated for one-to-many association when precondition specifies the association `asso` of object `ob` excludes object `addOb`, and postcondition specifies the association `asso` of object `ob` includes object `addOb`. Atomic action `addOneToOneAssociation` is generated for one-to-one association when postcondition specifies the association `asso` of object `ob` is object `addOb`. This is all `create` taxonomy. The `read` actions may be specified in both pre and post conditions. The atomic actions `findObject` and `findObjects` are generated when the contract specifies selection any object `ob` or objects `obs` from all the instances of `Classifier` under the specific conditions. The conditions can be disjunction or conjunction together. The objects can be retrieved from association. Therefore, the actions `findAssociationObject` and `findAssociationObjects` could be generated when the contract specifies though object `o` and association `asso`. The state of object could be checked when the contract specifies the attribute `attri` of object `ob` with comparison operator `op` and value. The object and collection of objects can be invoked by standard operations such as `oclIsNew()` and `size()`. The actions `standardOperationToObject` and `standardOperationToObjects` could be
generated when the contract has specified. The state of the attribute of object, object or the collection of objects could be checked. That is checkAttributeState, checkObjectState, and checkCollectionState charged. This is all about read actions. For the updating object actions, actions updateObjectWithNew and updateObject are generated when the condition specifies that updating attribute attri of object ob is equal to some specified value or depends on the pervious state of this object. For the delete actions, they are opposite to create actions. E.g. the contract ob.oclIsNew() for creating object, the contract of deleting object is ob.oclIsUndefined() = true. This is all about the operation contract to the CRUD atomic actions. In the next part, we will show how does the generation algorithm make the translation rules work.

C. Business Logic Generation Algorithm

The operation contract contains input and output variables of operation, the operation can only be executed when the precondition is evaluated to true, postcondition is satisfied after operation execution. In order to redundancy, the common part of precondition and postcondition could be extracted to definition part of contract such as findObject and findObjects. The algorithm to generate business logic is listed in Alg. 1. Firstly, operation signature is generated by the input variables of operation contract. Then the common part of precondition and postcondition defined in definition part of contract generate findObject and findObjects code. Moreover, like if command in Java, condition judgment skeleton is generated, the precondition generate code inside of condition judgment part, postcondition generate in the then part. In the else part, self-defined Java exception PreconditionsIsNotSatified is generated to represent this exception will be thrown when precondition is not satisfied before the operation executing. For each atomic expression in precondition, checkAttributeState is generated if atomic expression is checking attribute state expression, checkObjectState is generated if atomic expression is checking object state expression, checkCollectionState is generated if atomic expression is check collection state expression. For each atomic expression in postcondition, createObject is generated if the expression is create object expression, addOne-to-ManyAssociation is generated if the expression is to add one-to-many association, addOneToOneAssociation is generated if the expression is to add one-to-one association. updateObject is generated if the expression is to update object expression based on previous state of object, updateObjectWithNew is generated if the expression is to update object not depends on the previous state of object. releaseObject is generated if the expression is to delete object, removeOneToManyAssociation is generated if the expression is to remove the one-to-many association, removeOneToOneAssociation is generated if the expression is to remove the one-to-one association. This is the algorithm about generation business logic from operation contract. Next subsection will show the case how this algorithm works for borrowBook contract.

Input : Operation Contract
Output: Business Logic

// generation signature
generate operation signature;
// generation definition code
for all the selection operations in definition part do
    if operator is "any" then
        generate findObject code;
    else
        generate findObjects code;
    end
// generation contract skeleton
generate conditional judgment skeleton;
// generation precondition in skeleton
for all the atomic expression in precondition do
    if atomic expression is checking attribute then
        generate checkAttributeState code;
    else if atomic expression is checking object then
        generate checkObjectState code;
    else
        generate checkCollectionState code;
    end
// generation postcondition in skeleton
for all the atomic expression in postcondition do
    switch atomic expression do
        case create object expression
            generate createObject code;
        case add one to many association expression
            generate addOnetoManyAssociation code;
        case add one to one association expression
            generate addOneToOneAssociation code;
        case update object expression by previous state
            generate updateObject code;
        case update object expression
            generate updateObjectWithNew code;
        case delete object expression
            generate releaseObject code;
        case remove one to many association expression
            generate removeOneToManyAssociation code;
        case remove one to one association expression
            generate removeOneToOneAssociation code;
    endsw
end Algorithm 1: Business Logic Generation
D. Example: Borrowing Book

The complete contract of borrow book is presented in Fig. 3. The reason why we choose this operation is `borrowBook` involves main entities of library management system, the executing path depends on other objects state such as student state, borrowing state, and reservation state. This is most important and complex operation in library management system. The inputs of `borrowBook` are `uid` of entity user and `barcode` of entity `copy`. In the definition part, `uid` and `barcode` are used to find instances of `User`, `BookCopy` and `Reserve`. There are two main successful executing paths: The one is user reserved this copy, then borrows this copy. The other is the user directly borrow the book without any reservation. In any circumstance, the instances of `user` and `copy` must be validated before executing, which are defined in precondition. The status of `user` must be normal, not suspended and loaned number is not exceeded the specific number (Bachelor 20, Master 40, PhD students and teachers 60). In the first executing path, the `copy` must be reserved and on the hold shelf, the person who reserved this copy must be himself, that will make the instance of `reserve` valid, and the property `isReservedClosed` of instance of `reserve` must be false. On the another path, the user can directly borrow this copy when the status of copy is available. After borrowed this copy, an instance of `loan` is created, the property `LoanDate` is set as the date of today, `DueDate` is set as today after specific days corresponding to whether this user is student or not. The associations among this `loan`, `user` and `copy` are linked. The loaned number of user is plus one. If the user is in the first executing path, the property `isReserved` of copy instance is false, and the property `isReservedClosed` of reserve instance is true. Finally, the status of copy is `CopyStatus::LOANED`.

The above is all the precondition and postcondition of borrowing book. After running Alg. 1 the result is showed in Fig. 3. Firstly, operation signature is generated with input and output variables. The `findObject` code for the specific user with the same `uid` of input variable is generated. Unlike Java EE entity manager provided `find` method, which can only find the object according to the key property, our entity manager could be adapted for the different domain model, get all the instances of specific entity, then find the desired instance according any property of entity. Then the precondition part of contract is translated into the conditional judgement inside of `if` command, E.g, the `checkObjectState` is generated to check whether the found instances `user` and `copy` are undefined or not. All the standard operations are implemented in `StandardOPS` class, because of the limitations of space, we can not mention too much here. You can download and check from our update site. For the `checkAttributeState` marked in the figure, the master student can not loan book beyond or equal to 40, the...
code is generated accordingly. After all atomic expressions of precondition are translated, postcondition translation will start. According to the contract, a new instance loan is created, the createObject code is generated by invoking the createObject API of entity manager. As we known, the association from the entity loan to copy is one-to-one (One loaned record belongs to only one copy). Therefore, the addOneToOneAssociation code is generated by invoking the add operation of entity copy. For the updating action, E.g, after borrowed the copy, the copy status must be as LOANED. We use :: to represent enum type. For the copy state is loaned, the enum CopyStatus is the value of CopyStatus::LOANED. The corresponding updateObjectWithNew code is generated to set the state of copy as CopyStatus::LOANED. For the loaned number, the value must plus 1 based on previous loaned number, the updateObject code is generated to get previous loaned value first, then set the value as previous value plus 1. That is the all code generated from contract for borrowBook by Alg. [1]

In the next section, we will show the meta model of requirement model, persistence layer of the requirement model, how does persistence layer generate from that requirement model.

IV. REQUIREMENT MODEL TO ENTERPRISE APPLICATIONS

In the previous section, the generation business logic from operation contract is presented. However, the operation contracts can not be directly retrieved from target domain. The requirement model are needed to support retrieving requirements incrementally and iteratively. In this section, the requirement model implemented in RMCode are presented. Business logic is already generated from operation contract, business layer contain all the generated business logic and arrange them into services. The last generation work is to generate persistence layer from the conceptual model of requirement model. Then the enterprise applications with generated layers can provides service to other layers (e.g. GUI layer).

A. Requirement Model

To support both graphic and textual requirement model, and bi-directionally synchronization, the meta model need to be present first. Then mapping each elements in two model to the same meta model. Requirement should be obtained incrementally. Usually, starting from participated actors in the system, use cases are obtained according to the actors, service is used to arrange operations mapped from use cases, conceptual model is to construct data structure of the system. Operation is precisely defined by contract. Therefore, requirement model should include at least following parts: actor with use cases, service to arrange operations, conceptual model to capture conceptual domain, contract of operations. The requirement model proposed in our tool RMCode is showed in Fig 5. For the graphic model, actor with use cases can be represented as use case diagram, conceptual model can be described as conceptual class diagram. However, graphic is not good for specifying the operation contract, the textual model is a good supplementation for this shortage. Therefore, using both graphic model and textual model are a good way to retrieve requirements effectively and correctly.

B. Enterprise Application

Our target is to generate two layers of enterprise application. The business logic is already generated by Alg. [1] The two remaining work are generate business logic by arranging business logic into services and generate persistence layer from conceptual model. The target is showed in Fig 6. The

Fig. 5: Requirement model in RMCode

Fig. 6: Enterprise Applications
Fig. 4: The Meta Model of Requirement Model

Input : Requirement Model  
Output: Enterprise Applications  

// generation persistence layer  
// generation entity class  
for all the entity in conceptual model do  
    generate entity class code;  
end  

// generation entity manager  

// generation business layer  
// generation business logic  
for all operation contract do  
    executing algorithm 1;  
end  

// generation skeleton services  

// generation business logic  
for all generated business logic do  
    generate services code into corresponding services code;  
end

Algorithm 2: Enterprise Application Generation

In the next section, the proposed approach is demonstrated on the whole case study of library management system to analyse the performance.

V. PERFORMANCE

The case study of library management system is throughout this paper. It is a well known case study. For the business logic generation, we only show the operation BorrowBook. For purpose of validation effectiveness the proposed approach and tool, the more use case should be presented. The core use cases are makeReservation, borrowBook, returnBook, renewBook and checkOverDue with compute over due fee in which third part services will be invoked in some situations. For the case of renewBook, the borrowed book only could be renewed when there is no reservation on it, renew time must be before the due date, and for the different users such as student and teacher, bachelor and master students, the renew times and the holding time are totally different.

We compared each operation with the measurement of LOC (line of code), the number of atomic actions (AA), generation time (GT), and execution time (ET). Our experiment is running on the normal desktop, with 3.5 GHz Intel Core i5, 16 GB 1600 MHz DDR3, and 500 GB Flash Storage. The result is showed in Tab. II. The first impression of our approach is very effective. The generation time is all under 10ms. The generation time and execution time are the average of three times of experiments. The BorrowBook is most complex business logic in library management system, it has 70 lines of code, 44 atomic actions contained. Even though, the generation time is only 8.54247 ms, and the execution time is 525.34686 ms under 1ms, because the precondition contain nested paths, that take more time to check. The main use case contain the average of 20 atomic actions, that demonstrate our approach has the capability to apply to other enterprise applications. For now, RQ1 can answer here: Yes, enterprise applications could be automatically and effectively generated from requirement model. However, there are some limitations in our approach. RQ2 will be discussed in the next section.

VI. LIMITATION

For operation contract aspect, RMCode could generate code from the specification written in Tab. I. In addition, RMCode supports if, let grammar of OCL. Third-parts APIs is also supported in our requirement model. However, if you write
### TABLE III: The Comparison of Code Generation Tools

| Name                  | Requirement Model (UML) | Open Source | Organization            | OCL Support                                      | Code Generation                                      |
|-----------------------|-------------------------|-------------|--------------------------|--------------------------------------------------|-------------------------------------------------------|
| Rational Rose Family  | √                       | IBM         | Supported                | Java/C#/C++ Entity Class                         |                                                       |
| MagicDraw             | √                       | No Magic    | (Dresden OCL) 2.3        | Java/C#/C++ Entity Class                         |                                                       |
| Enterprise Architect  | √                       | Sparx Systems | Supported               | Java/C#/C++ Entity Class                         |                                                       |
| Visual Paradigm       | √                       | Visual Paradigm | No                     | Entity Class with ORM / REST API supported       |                                                       |
| Papyrus UML           | √                       | Eclipse Foundation | (Eclipse OCL) 2.4   | Java Entity Class                                 |                                                       |
| UML Designer          | √                       | Obeo Network | (Eclipse OCL) 2.4        | Java Entity Class                                 |                                                       |
| Eclipse Modeling      | √                       | Eclipse Foundation | (Eclipse OCL) 2.4   | GUI (EMF Forms)/ Entity Class with ORM (EMF/CDO) |                                                       |
| USE                   | √                       | Bremen University | Supported             | No                                                |                                                       |
| rCOS modeler          | √                       | UM and UNU-IIST | No                     | No                                                |                                                       |
| AutoPA                | √                       | UM and UNU-IIST | (Octopus) 2.0           | OO Code                                           |                                                       |

### TABLE II: The results of library management system

| UseCase               | LOC | AA  | GT (ms) | ET (ms) |
|-----------------------|-----|-----|---------|---------|
| searchBookByBarCode   | 27  | 4   | 9.82555 | 0.22312 |
| searchBookByTitle     | 23  | 4   | 1.00725 | 0.45902 |
| searchBookByAuthor    | 23  | 4   | 0.7482  | 0.64243 |
| searchBookByISBN      | 23  | 4   | 1.25654 | 0.24375 |
| searchBookBySubject   | 27  | 4   | 1.96138 | 0.54212 |
| addBook               | 14  | 3   | 3.32883 | 1.42846 |
| deleteBook            | 29  | 8   | 9.03951 | 1.42464 |
| recommendBook         | 28  | 12  | 2.94632 | 1.43221 |
| queryBookCopy         | 24  | 3   | 1.21512 | 1.34528 |
| addBookCopy           | 27  | 11  | 2.06911 | 9.62374 |
| deleteBookCopy        | 25  | 7   | 1.20971 | 1.75343 |
| makeReservation       | 41  | 17  | 3.43437 | 0.19412 |
| cancelReservation     | 46  | 19  | 2.68352 | 0.45594 |
| borrowBook            | 70  | 44  | 8.54247 | 525.34686|
| renewBook             | 67  | 32  | 6.02692 | 0.46449 |
| returnBook            | 65  | 25  | 4.17085 | 0.94083 |
| payOverDueFee          | 39  | 14  | 7.69423 | 0.6023  |
| listBorrowHistory     | 15  | 6   | 3.97312 | 0.65607 |
| listHoldingBook       | 34  | 7   | 6.79587 | 1.44897 |
| listOverDueBook       | 41  | 10  | 3.98236 | 1.31842 |
| listReservationBook   | 34  | 9   | 4.69292 | 0.71341 |
| listRecommendBook     | 28  | 7   | 1.65816 | 0.86342 |
| checkOverDueDayAndFee | 53  | 40  | 7.98976 | 2.53564 |
| dueSoonNotification   | 33  | 8   | 3.35992 | 0.43919 |
| countDownSuspensionDay| 31  | 11  | 4.29009 | 0.24055 |
| createUser            | 14  | 3   | 0.94726 | 57.87105|
| deleteUser            | 25  | 6   | 0.94145 | 2.34123 |
| queryUser             | 25  | 4   | 0.65654 | 1.23412 |
| createLibrarian       | 15  | 5   | 0.41938 | 1.35931 |
| deleteLibrarian       | 25  | 6   | 0.71815 | 1.02476 |
| queryLibrarian        | 25  | 5   | 0.74347 | 0.55311 |

For enterprise application aspect, this paper focuses on generating business logic. The object state could be persistence into the file, we don’t take database into account in this time. That is all RQ2 care about.

VII. RELATED WORK

Commercial tools usually support automated code generation. Except Visual Paradigm (VP) in Tab.III most of them support OCL-based contract, entity class can be automated generated as multiple programming language, but VP supports entity class generation with ORM supported and provided Restful-based web service wrapper, Papyrus UML is well developed and widely used open source tool by Eclipse foundation. Furthermore, under eclipse modelling projects, EMF Forms supports GUI automated generation from domain model, CDO provides the ability to support ORM in EMF model. The new version of Enterprise Architect support generate business logic from design model (e.g sequence diagram). However, like the related works mentioned in the introduction section, all the commercial tools can not generate business logic without explicitly a design model.

For automated composition of service computing, the survey provide the overview of this approaches. There are two primary paradigms for service composition: top-down and bottom-up paradigms. For top-down paradigm, the complex workflow is designed manually, and bottom-up paradigm can composite services automatically by AI method. presents a mixture paradigm architecture, unlike top-down paradigm, HTN to plan workflow is utilized instead of designed workflow, and like top-down paradigm to discover services, the best service is selected. If no existed service is matched, same as bottom-up paradigm, the nested composition procedure will be triggered to fulfill the requirement. Nevertheless, full automatic approaches usually are not the best solution for world-wide problems. Especially for human dominant activities. Therefore, presents an modified mixture composition paradigm, which combines top-down and bottom-up paradigms by designing a workflow for discovering and selecting service foremost, when no service is matched or discovered, a bottom-up nested composition procedure into the file, we don’t take database into account in this time. That is all RQ2 care about.

http://www.eclipse.org/ecp/emfforms
http://www.eclipse.org/cdo/
https://eclipse.org/modeling/emf/
will be triggered. Nevertheless, the automated generation of service workflow would be failure if no one existing service is matched or existing services could not be composed to satisfy the requirements.

The advantages of academic tools are supported by well formed mathematic. USE (UML-based Specification Environment) [15] supports analysts, designers and developers in executing UML models and checking OCL constraints and thus enables them to employ model-driven techniques for software production. rCOS (Refinement of Component and Object Systems) modeler [16][17][18] is supported refinement calculus both of component-based and object-oriented model. It uses first-order logic to specification the contracts of operations. However, those tools do not support generate any code and prototype, AutoPA (Automated Prototype Generation and Analysis) [19][20] could generate business logic from OCL Specification and Java swing prototype, but both rCOS and AutoPA are not separate logic responsibilities from entity class, generation business logic only from precondition or postcondition, and AutoPA does not support textual requirement model.

VIII. Conclusions and Future Work

In this paper, we propose an approach which could automated generated enterprise applications from requirement model without explicitly design model, which is implemented as eclipse plugin named RMCode, a classic case study of library management system demonstrates the feasibility and efficiency. The tool supports the phase-based incremental requirement modeling. After acquiring requirement model, layered enterprise application could be automated generated without any effort. The new requirements could be easily added, then enterprise applications can be regenerated immediately, this approach could be useful for requirement engineer to find right requirement and boost the process of software development.

In the future, we will continue to enhance RMCode to support more enterprise application layers such database layer, and for the operation contract, we will take the more general case into account such as equation.

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