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Contribution to Software Development Method based on Generalized Requirement Approach

DISSERTATION

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Abstract

Requirements' gathering is one of the first steps in the software development process. Gathering business requirements, when the final product requirements are dictated by a known client, can be a difficult process. Even if the client knows their own business best, often their idea about a new business product is obscure, and described by general terms that contribute very much to common misunderstandings among the participants. Business requirement verification when the requirements are gathered using text and graphics can be a slow, error-prone, and expensive process. Misunderstandings and omitted requirements cause the need for revisions and increase project costs and delays.

This research work proposes a new approach to the business software development process and is focused on the client's understanding of how the business software development process works as well as a demonstration of the business requirement practices during requirement negotiation process..While the current software development process validates the business requirement at the end of the development process, this method implementation enables business requirement validation during the requirement negotiation phase.

The process of the business requirement negotiation is guided by a set of predefined questions. These questions are guidelines for specifying a sufficient level of requirement details for generating executable code that is able to demonstrate each requirement. Effective implementation of the proposed method requires employment of the GRA Framework. Besides providing guidelines for requirement specification, the Framework shall create executables and provide the test environment for a requirement demonstration.

This dissertation implements an example framework that is built around a central repository. Stored within the repository is the data collected during the requirement negotiations process. Access to the repository is managed by a Web interface that enables a collaborative and paperless environment. The result is that the data is stored in one place and updates are reflected to the stakeholders immediately.

The executable code is generated by the Generator, a module that provides general programming units that are able to create source code files, databases, SQL statements, classes and methods, navigation menus, and demo applications, all from the data stored in the data repository. The generated software can then be used for the business requirement demonstration. This method assumes that any further development process is built around the requirements repository, which can provide continuous tracking of implementation changes.

Besides readily documenting, tracking, and validating the requirements, this method addresses multiple requirement management syndromes such as the insufficient requirements description details provision, the IKIWISI ("I'll know it when I see it") Syndrome, the Yes, But Syndrome ("That is not exactly what I mean"), and the Undiscovered Ruins Syndrome ("Now that I see it, I have another requirement to add")."

Keywords

Generalized Requirement Approach, Requirement Management, Business Requirements, Software Development method, Requirement Negotiation Process

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1 Introduction

Gathering business requirements can be a difficult process, especially in cases when the final product requirements are dictated by a known client. Although the client knows his own business best, often his idea about a new product is obscure and described using general terms that greatly contribute to common misunderstandings. Business requirement validation in the case when requirements are gathered using text and graphics can be a slow, error-prone, and expensive process. Misunderstandings and omitted requirements can cause revisions that in turn increase project costs and delays

The later in a project that issues related to requirements are discovered, the greater are costs and delays. Discovering and modifying requirements in the Design Phase can be three to six times more expensive, in the Coding Phase it can be up to ten times more expensive, and in the Development Testing Phase it may reach fifteen to forty times more expensive. By the time the Acceptance Phase is reached, modification can become thirty to seventy times more expensive, and in Operation Phase it could well be forty to a thousand times more expensive. (Dragon Point Inc. 2008)

Architecture and design directly depends on the Requirement Specification. A misunderstanding or wrong interpretation of the requirement can lead to erroneous architectural and design decisions, which in turn propagate failure during coding and further project phases. One of the worst case scenarios is when wrongly implemented requirements are discovered after deployment on the production platform.

One research study reported that more than a quarter of completed projects contain only 25% to 49% of the originally specified features and functions (The Standish Group 1995).

The IBM Project Management presentation uses the Meta Group study to illustrate that 70% of large IT projects failed or did not meet customer expectations (IBM 2007).

The current methodology verifies requirements by using manual procedures, reviews, traceability matrices, and workshops. Today, prototyping as a requirement validation method has been mostly replaced by the agile software development approach. The current methods for requirement verification and validation are described in the Chapter 2 “Research Problems”.

This dissertation proposes a new approach to the software development process, called the Generalized Requirement Approach (GRA), to improve the requirements negotiation process and enable requirement validation during the requirement negotiation process. While the current software development process validates the business requirement at the end of the coding phase, this method implementation enables business requirement validation during the requirement negotiation process. The source code and executables are generated by the Generic Programming Units (GPU), which are part of the GRA Framework. The GRA Framework is the implementation of the GRA method, and this framework provides procedures for documenting and specifying requirements, and describes methods and libraries that are used to generate source code and executables. The questions that are part of the GRA Framework are guidelines for specifying a sufficient level of requirement details to successfully generate sources and executable code for requirement demonstration. Besides requirement documenting, tracking, and validating, this method addresses several requirement management syndromes that commonly make up the category of insufficient details provision (Bulajic et al. 2013a), including the IKIWISI ("I'll know it when I see it") Syndrome, the Yes, But Syndrome ("That is not exactly what I mean"), and the Undiscovered Ruins Syndrome ("Now that I see it, I have another requirement to add").

Utilized in this document are the standard definitions of terms according to the "IEEE Standard Glossary of Software Engineering Terminology", IEEE-Std 610.12 ("IEEE Standard Glossary of Software Engineering Terminology" 1990) in addition to the standard definitions of terms according to the Microsoft .NET technology ("Visual Studio and .NET Framework Glossary" 2013).

Regarding those terms where the definition differs from the IEEE-Std 610.12 standard and Microsoft .NET standards, they are additionally described in the Chapter 13 "Appendix A – Definition of Terms".

The proposed solution is implemented in the Microsoft .NET technology under Windows 7 Professional Operating System (OS), by using Microsoft .NET Framework version 4.5.50709, ASP.NET version 2012.3.41009, Visual Studio Express 2012 for Web, MySQL database version 5.6.10.1, MySQL Connector NET version 6.6.5, and C# Microsoft .NET language. Therefore, all examples in this dissertation are coded by using C# language and ASP.NET commands.

The solution presented in this dissertation is relevant for business and E-Commerce applications that are based on the user input, and storing and retrieving data that can be described by programming language and SQL available data types. The proposed solution is not recommended to applications that are based on the complex data models and relations, simulations, graphical applications, real-time applications, and complex algorithms.

The proposed solution can be implemented by using different technologies, for example, Java technology, but such implementation will require different technical platforms.

This dissertation is organized in the following chapters:

1. Introduction
2. Research Problems
3. Related Work
4. Traditional Software Development Method (SDM)

5. Generalized Requirement Approach (GRA)
6. Generalized Requirement Approach Framework (GRAF)
7. GRA Framework Validation
8. Summary of GRA Features and Comparison to other Approaches
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Chapter 2 “Research Problems” discusses the requirement verification, validation, and specification issues that contribute to false requirement understandings.

Chapter 3 “Related Work” presents software development methods and tools that have contributed to the software development process. The Chapter 3 “Related Work” presentation is limited to the major methods and tools that are currently used for software development.

Chapter 4 “Traditional Software Development Method (SDM)” is an overview of the current software development process structure that is common for the software development methods presented in the Chapter 3 “Related Work”.

Chapter 5 “Generalized Requirement Approach (GRA)” describes the proposed method for improving the software development process based on requirement validation during the requirement negotiation process. For successful requirements validation during the requirement negotiation, an automatically generated source code and executables are used.

Chapter 6 “Generalized Requirement Approach Framework (GRAF)” describes the GRA Framework, which is the implementation of the GRA method. The GRA Framework is responsible for guiding a user to specify requirements, store requirement descriptions in the structured text format, and generate source code and executables that are used for requirement validation.

Chapter 7 “GRA Framework Validation” describes the implementation of the Retail Store, a fictitious E-commerce application, which is used to validate the GRA Framework implementation.

Chapter 8 “Summary of GRA Features and Comparison to other Approaches” describes the differences between the solution proposed in this dissertation and current software development methods.

Chapter 9 “Generalized Requirement Approach (SDMGRA) Limitations” presents the limitations of the proposed method, as well as issues and obstacles that were discovered during implementation of the Retail Store application.

Chapter 10 “Research Contribution” describes the benefits of the proposed solution and its contribution to the software development process.

Chapter 11 “Conclusion” draws a final conclusion and proposes further work.

Chapter 12 “List of References” contains the list of literature used for writing this dissertation.

Chapter 13 “Appendix A – Definition of Terms” contains definitions of those terms that have definitions differing from the IEEE-Std 610.12 standard and Microsoft .NET standard.

Chapter 14 “Appendix B – Generating Source Code” is an example of the generating source code for PRODUCT form.

Chapter 15 “Appendix C – Retail Store Example” contains a full example of the Retail Store application, the fictitious E-Commerce application that is used for validation of the GRA Framework.

Chapter 16 “Appendix D – Retail Store Test Documentation” contains documentation that can be used for testing the generated source code with the Retail Store application, the fictitious E-Commerce application used for validation of the GRA Framework.

2 Research Problems

The focus of this research work is on requirement negotiation issues and the verification and validation of requirements during the requirement negotiation phase. The software development process depends on proper understanding of these requirements. Propagating a misunderstanding from the requirement negotiation phase to later project phases can be expensive and badly affect the project’s duration and budget. This research work identifies and discusses several requirement negotiation issues: the typical levels of insufficient details seen during a project, (Bulajic et al. 2013), and the common issues related to the requirements’ verification and validation.

The verification process is defined as “(1) the process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase. Contrast with: validation. (2) Formal proof of program correctness” (“IEEE Standard Glossary of Software Engineering Terminology” 1990).

The IEEE Standard 610.12 defines a validation as “The process of evaluating of system component during or at the end of the development process to determine whether it satisfies requirements. Contrast with: verification” (“IEEE Standard Glossary of Software Engineering Terminology” 1990).

The software development process needs planning, estimation, and resource allocation, and is a costly process that needs to be justified by the software product. Although it can be argued that it is most important that the developer understand the customer’s requirement, the process of documenting requirements and decisions is equally important, especially in case of distributed software development teams and outsourcing (Bulajic and Domazet 2012).

“Developing a software system without a specification is a random process. The implementation is doomed to be modified, sometimes forever, because it never precisely matches the client’s needs. The goal of a specification is to capture the client’s requirements in a concise, clear, unambiguous manner to minimize the risks of failure in the development process. It is much cheaper to change a specification than to change an implementation”. (Frappier and Habrias 2001)

Writing requirement specification documents can be a difficult process. Different stakeholders, users, managers, architects and designers, and developers need different kinds of information (Boehm et al. 2001). Before implementation of the requirement specification, the requirements need to be verified. The requirements verification process based on the manual reviews can be a slow, expensive, and error-prone process (Sommerville 2001). Pictures, diagrams, and textual explanations are important tools for improving understanding, but these means are not a sufficient guarantee to avoid misunderstandings. The verification process based on the manual reviews cannot often solve the requirements syndromes that arise, such as the IKIWISI (“I’ll know it when I see it”) Syndrome, the Yes, But Syndrome (“That is not exactly what I meant”) and the Undiscovered Ruins Syndrome (“Now that I see it, I have another requirement to add”) (Leffingwell and Widrig 2000).

In software development, the working product and User Acceptance Tests validate requirement specifications. Waiting to determine whether the development process will create a successful software product is a risky and costly method. For project success it is crucial that the requirement specifications are correctly quantified before the start of the next software development process phase.

The issues that can contribute to false requirement understandings are:

1. Requirement elicitation and verification issues,
2. Requirement validation issues,
3. Missing appropriate tools.

2.1 Requirement elicitation and verification issues

The requirement elicitation process can be described as an understanding of the application domain, requirements collecting, and sorting and prioritizing input. The most important output from this process is the Requirement Specification document. For requirement elicitation and validation, good practice in requirement engineering, according to Wiegers (Wiegers 2003), recommends the following steps:

1. Requirement elicitation,
2. Requirement analysis,
3. Requirement specification,
4. Requirement verification.
5. Sommerville describes the requirement engineering good practice as (Sommerville 2001):
6. Feasibility study,
7. Requirement elicitation and analysis,
8. Requirement specification,
9. Requirement verification,
10. Requirement management.

Sommerville (Sommerville 2001) includes a Feasibility study in Requirement Engineering as a step that precedes the Requirement Elicitation and describes an iterative approach between the Requirement elicitation and analysis phase and the Requirement specification phase, as well as between the Requirement specification and the Requirement verification phases.

Rational Unified Process (IBM Rational Unified Process (RUP) 2012), applies a structured method as a system specification.

"The Rational Unified Process applies a structured method in developing a set of graphical system models that act as system specifications. The set of models describe the behavior of the system and are annotated with additional information describing, for example, its required performance or reliability". (Sommerville 2001)

Sommerville (Sommerville 2001) argues that although the structured method's role in case of requirement engineering can be important, it does not provide effective support for the early requirement elicitation process.

Wiegers (Wiegers 2003) offers a long list of the steps that belong to the Requirement elicitation phase. This inventory starts with the definition of the requirements development process, writing a vision and scope document, and continues over to the identification of stakeholders, using workshops and other learning techniques about the customer's current job, and possible system improvement. (Wiegers 2003:47)

Leffingwell and Widrig (Leffingwell and Widrig 2000) describe the following technique used for requirement elicitation:

- Interviewing and questionnaires,
- Requirements workshops,
- Brainstorming and idea reduction,
- Storyboards,
- Use cases,
- Role playing,
- Prototyping.

Sommerville sees prototyping as a requirement verification technique and specifies the following techniques for the requirement validation process (Sommerville 2001):

1. Requirement reviews,
2. Test case generation,
3. Automated consistence analysis, in case requirements are specified as "a system model or formal notation."

For requirement verification, Wiegers (Wiegers 2003) favours the technique of a formal inspection of the requirements document accomplished inside of small teams where different views are represented, such as an analyst, a customer, a developer, and a tester. This technique is supported through testing requirements by developing functional test cases and specifying acceptance criteria (Wiegers 2003).

In cases of the RUP, verification can be done by using a traceability feature (Leffingwell and Widrig 2000). A requirement or a need in RUP terminology is linked to a feature. A feature is linked to a software requirement and use case. The use case is linked to test cases. If some of the links are missing it is considered an indication that the requirement is not properly verified. Requirement verification in this case is considered done only if a link to a use case and a test case exists.

Creating a traceability matrix is a time-consuming process, and depends on personal experience and competence. The quality of the final results, when multiple people are involved, even inside the same IT company, can differ significantly.

"By its very nature, a specification cannot be 'proved' to match the client's requirements. If such a proof existed, then it would require another description of the requirements. If such a description is available, then it is a specification." (Frappier and Henri 2001)

Manual requirement verification is a whiteboard and pencil technique, and drawing diagrams on a computer screen does not make any difference. Even if the future solution can be visualized, it is still far from the working system. The manual process does not ensure requirement understanding or the specification of system features that are not desired, unused, or even counterproductive.

In this dissertation a solution is proposed that validates the requirement during the requirement negotiation phase. The validation of the requirement is accomplished by generating source code and executables from the structured textual description of requirement. The generated executables are used for requirement clarification and a better understanding of the requirement.

2.2 Requirement validation issues

The validation process is a confirmation of the software product implementation after the software application is installed in a test environment that is as similar as possible to the production environment. It is assumed that the test and development environments are completely separated and do not share code, data, or configuration settings. The requirement validation in this case is a User Acceptance Test (UAT).

If the requirement engineering process is properly accomplished, then the acceptance criteria, as well as test cases and expected results, are already known.

The following are issues that can arise during the requirement validation process:

- Time gap between client requirements specification and requirements validation,
- Time gap between specification of the acceptance criteria, generating of test cases, and releasing software,
- Amount of time available for User Acceptance Test,
- Resources availability for User Acceptance Test.

A time gap between requirements specification and requirements validation is illustrated in Figure 1:

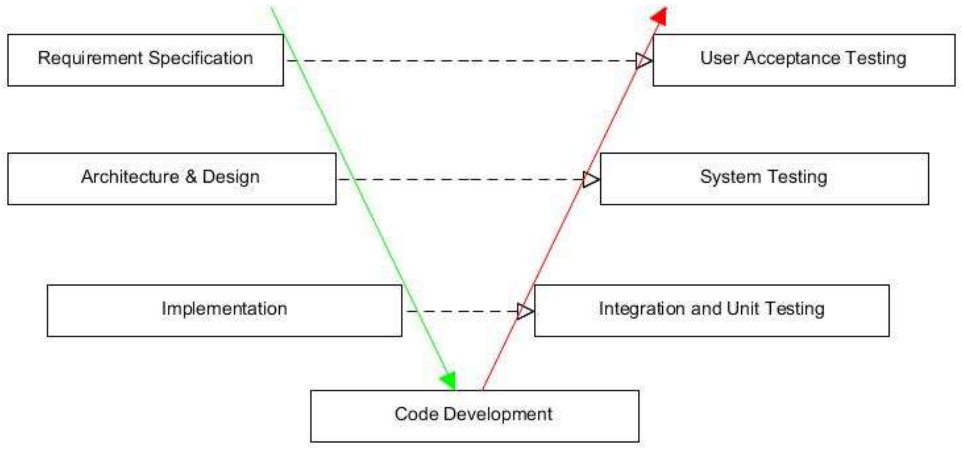


Figure 1 V Model

The time gap between requirements specification and requirements validation is equal to the sum of time spent during Architecture & Design, Implementation, Code Development, Integration and Unit Testing, and System Testing processes.

The green line represents a part of the Software Development Process where verification of the requirements and design is done on the conceptual level, by using tools such as interviews, drawings, charts, and diagrams, and supported by textual descriptions. The red line represents the requirement validation process when accomplished by testing code developed in the Code Development phase.

Although it could reduce time during conceptual level verification, final validation and approval is done during User Acceptance Testing. If a time gap between Requirement Specification and User Acceptance Testing is longer than normal, requirement changes are most likely. If this process is shorter than normal, the requirement could have been misunderstood. In cases where the requirement is wrongly implemented, it will require additional work to correct the implementation according to the client’s desires.

When projects use agile development methodologies, a limited part of the requirements are validated at the end of each iteration. The agile approach cannot assure that the next iteration, as well as the final iteration, will not discover conflicts that will require redesign and refactoring work.

Acceptance criteria need to be specified during the requirement negotiation process. Test cases need to be generated shortly after as a part of the requirement validation process. Software is released some weeks or months later. That which seems well defined during requirement negotiation in the Requirement Specification phase can succumb to the Yes, But Syndrome (“That is not exactly what I mean”), and/or the Undiscovered Ruins Syndrome (“Now that I see it, I have another requirement to add”). (Leffingwell and Widrig 2000)

The amount of time available for the User Acceptance Test (UAT) is limited. UAT is a process testing a limited number of critical functionality. Even this critical part cannot be tested properly, because the number of combinations and interactions can be high, while the sufficient amount of variable test data is not yet available. Test resources quality and availability are important factors during UAT. Introducing new people that were not involved in the previous discussions and do not know the requirement's history can be a result-disturbing factor.

This dissertation shows that requirements validation can be accomplished during the requirement negotiation process. The approach proposed in this dissertation demonstrates the requirement during requirement negotiation. Requirement demonstration is used for requirement clarification and improved requirement understanding.

2.3 Missing Appropriate Tools

The first step in the software development process is acquiring the requirement description and clarification. While most of the existing tools provide registration, categorization, and querying/reporting capabilities, the procedure for guiding a user to correctly specify requirements is not supported. The requirement is usually described by free text and structured according to the best understanding of the user. The guidelines for specifying requirements are expressed by using general terms that cannot be easily applied to the requirement specifics and, by their nature, are difficult to be measured objectively.

The IEEE 1998b standard describes the characteristics of a good requirement definition practice as ("IEEE Recommended Practice for Software Requirements Specification" 1998):

1. Correct,
2. Unambiguous,
3. Complete,
4. Consistent,
5. Ranked for importance and/or stability,
6. Verifiable,
7. Modifiable,
8. Traceable.

The Unified Approach (Leffingwell and Widrig 2000) added a ninth characteristic, Understandable.

Other authors, such as Wiegers, describe the characteristics of excellent requirement statements as (Wiegers 2003):

1. Complete,
2. Correct,
3. Feasible,
4. Necessary,
5. Prioritized,
6. Unambiguous,
7. Verifiable.

Wiegers (Wiegers 2003) distinguishes between a Requirement Description and a Requirement Specification, and a good Requirement Specification is described as:

1. Complete,
2. Consistent,
3. Modifiable,
4. Traceable.

The author of this dissertation would add to this list another characteristic, “Elaborated”. The generalizations, enumerations, algorithms, nonspecific statements and observations, state transitions, and inputs and expected outputs needs to be described sufficiently. Sufficiency in this case means that general statements are avoided, such as “other”, “some”, or “few”, or enumerations are not left unfinished, as, for example, “etc.”. Requirement specifications shall be detailed enough to be ready for translation to the machine’s or implementation’s specific language.

While other authors have focused on making requirements understandable for humans, the author of this dissertation believes that it is even more important to make it understandable for the machine, in this case a computer. This is because the end of the journey for a requirement is implementation in the final software product.

A requirement and specification are not necessary the same. A requirement is the customer’s description about a needed or wanted solution. While the customer’s viewpoint can be described by plain text and contain general descriptions, specification requires elaborated description.

Frappier and Habrias tried to answer the question of “What’s the difference between a specification and a requirement? The quotation above gives a clue: the requirement is what somebody wants, while the specification says what the system that is supposed to ‘match’ those wants should actually do. This distinction introduces one of the fundamental problems in requirements engineering — showing that the requirements are met, first by the specification and then by the actual implementation itself” (Frappier and Habrias 2001).

Business requirement gathering is a manual process. Documenting requirements is also a manual process, which uses manual tools, such as interviews, reviews, diagrams and drawings, or UML. Yet, despite that these tools' purpose is for requirement clarification and understanding, these tools are insufficient for guaranteeing that there will be an avoidance of misunderstandings.

Even in cases when recommendations about specifying a good requirement are clear and elaborated, as well as supported by valid examples, proper requirement specification still can be a challenge.

The solution offered in this dissertation guides stakeholders during the requirement negotiation process to specify requirements with a sufficient level of details (Bulajic et al. 2013).

3 Related Work

The history of software development is a chronicle of the continuous search for a better methodology and tools that can improve the software development process. This chapter is a presentation of the software methodologies and tools that have thus far contributed to the improvement of the software development methodology. The presentation in this chapter is limited to the major methods and tools that are currently used for software development.

The software development process can be very complex and there is not a single method or tool in existence that can satisfy the entire spectrum of issues that a software development process will need to solve. Each methodology or tool available is to solve a particular set of issues and can be successfully used on a class of related problems.

This chapter's presented methods are based on the implementation of the Software Development Method (Benington 1956; Royce 1970). The Software Development Method (SDM) is a process of software development that can be described by the following development phases and activities:

1. Analysis – system requirements management,
2. Architecture & Design – system design,
3. Development – internal design and coding ,
4. Test – test and validation,
5. Deployment – operation and maintenance.

The SDM is a structured approach to software development. The purpose of the SDM is the production of high-quality software in a cost-effective way (Sommerville 2001). The structuring process purpose is to enable process planning and controlling. The SDM process structure is implemented in the different software methodologies, sequential and iterative, incremental and evolutionary, rapid application development and prototyping. For this dissertation, the SDM approach is called the Traditional Software

Development Method and a more detailed description can be found in Chapter 4 “Traditional Software Development Method (SDM)”.

3.1 Sequential Software Development Method

The sequential approach to the SDM is identified by the Waterfall (Benington 1956; Royce 1970) software development method. The traditional requirement management approach is often identified by the Waterfall software development method, where comprehensive requirement analysis and documenting is completed before starting the next project phase. Requirements verification is accomplished by manual reviews and a traceability matrix. Requirements are validated in the test phase. The Waterfall method is most appropriate for large projects where requirements are stable and do not change often.

By the 1950s, software developers were already aware that the development of the large computer programs was a challenge and suggested an evolutionary software development approach (Benington 1956).

For traditional requirement management, the time difference between requirement specification and requirement validation can be months or even a year in the large software development projects. Software requirements are subject to continuous changes. If the time difference grows longer, then the probability that the requirement will be changed becomes more likely. Analysis shows that an average of 25% of requirements change in the typical project, and the change rate can go even higher, to 35% to 50% for large projects (Larman 2005).

Doctor Winston W. Royce wrote about the challenges that are introduced during development in the large software system: “The required design changes are likely to be so disruptive that the software requirements upon which the design is based and which provides the rationale for everything are violated. Either the requirements must be modified, or a substantial change in the design is required. In effect, the development process has returned to the origin and one can expect up to a 100-percent overrun in schedule and/or costs” (Royce 1970).

Other statistics show an “average of 45% of the features in Waterfall requirements are never used, and early Waterfall schedules and estimates can vary up to 400% from the final actuals” (Larman 2005).

3.2 Evolutionary Software Development Method

“The EVO development model divides the development cycle into smaller, incremental Waterfall models in which users are able to get access to the product at the end of each cycle. The users provide feedback on the product for the planning stage of the next cycle and the development team responds, often by changing the product, plans, or process. These incremental cycles are typically two to four weeks in duration and continue until the product is shipped.” (May and Zimmer 1996*)*

The EVO development model fits best to the middle-size and larger software development projects.

Hewlett-Packard experimented with implementation of the Evolutionary Development method (EVO) "to improve software development process, reduce the number of late changes in the user interface, and reduce the number of defects found during system testing". (May and Zimmer 1996*)* The first failed attempt lasted a year and half, and four developers delivered over 30 releases in one- or two-week delivery cycles. The second attempt involved six to eight project managers and approximately sixty engineers that used four- to six-week scheduled releases, and failed to deliver the expected features and expected results (May and Zimmer 1996).

The third attempt involved one project manager and eight engineers using a modified approach and called it "phased development". For the first month they worked on a prototype, and demonstrated and collected feedback. After four to six months of implementation, they delivered world-class product (May and Zimmer 1996).

The experience gathered from the Hewlett-Packard experiment recommends:

1. Small teams,
2. Start coding as earlier as possible,
3. Demonstrate and use feedback to improve product.

The Hewlett-Packard experiment shows that short iterations and release cycles, such as one to two weeks maximum, can be an issue. The short iterations are recommended only in cases when the release needs clean-up, performance tuning, or correction of blocking errors. Each release introduces overhead and uses up resources and available time.

"Successful use of EVO can benefit not only business results but marketing and internal operations as well. From a business perspective, the biggest benefit of EVO is a significant reduction in risk for software projects. This risk might be associated with any of the many ways a software project can go awry, including missing scheduled deadlines, unusable products, wrong feature sets, or poor quality. By breaking the project into smaller, more manageable pieces, and by increasing the visibility of the management team in the project, these risks can be addressed and managed." (May and Zimmer 1996)

The Hewlett-Packard experiment, with regard to full-scale industrial projects, shows the importance of creating prototypes and early solution demonstration for reducing risk and improving final product quality.

3.3 Iterative and Incremental Software Development Method

An iterative and incremental approach breaks the project up into more pieces or phases, where each phase output is functional software that implements a limited set of requirements. The last phase is supposed to deliver the fully functional software that implements all the requirements. Each phase adds a new value to the existing software and incrementally builds the entire product. The requirements are refined during planning of the next phase, and corrected by a better understanding of what is needed, information that is collected during the development phase and feedback received from a client (Cockburn 2008). The iterative and incremental approach reduces the risk that the final product will not satisfy customer expectation.

The agile software development approach is the implementation of the iterative and incremental software development method (Beck 2001). The agile software development approach does not wait until all requirements are specified, nor does it require that the whole requirement is specified. Development starts as soon as a part of the requirement is considered to be understood (Beck 2002).

The agile approach best fits small projects and small project teams. According to the agile method philosophy, requirements are subject to continuous changes, and there is no reason to waste time on detailed specifications. The agile method relies on a fast release delivery that should provide requirement clarification and quick user feedback.

The agile method approach also incorporates the Waterfall method, and divides an entire project in short Waterfall cycles. Short Waterfall cycles can make a significant difference when requirements are not well known or are changed frequently. Another important difference is that frequent deliveries cause frequent test execution and feedback from clients and testers. Mistakes and failures are discovered earlier.

However, creating releases is not free, and each release requires additional time for building, documenting, and testing. Agile development assumes that a payoff is quick at discovering any misunderstandings of requirements, and that there will be an improvement of final software product quality as consequence of testing more often and user feedback.

The agile development approach is criticized for scope creep and a lack of project planning. Without knowing all the requirements it is not possible to know when a project will be completed in order to do project scheduling, budget planning, and resource allocation.

McConnell (McConnell 2004) agrees that construction is the only activity during software development that cannot be avoided, but he recommends proper project planning, and states that the “assertion that architecture, design, and project planning aren’t useful on modern software projects is not well supported by research, past or present, or by current data” (Mc Connell 2004:29).

Today the agile software development approach is implemented in several different software development methods, such as Extreme Programming, SCRUM, Test-Driven Development (TDD), and Feature-Driven Development (FDD).

3.3.1 SCRUM

In 1993, Jeff Sutherland created SCRUM—an agile software development method (Sutherland and Schwaber 2011). SCRUM is best known for its uses in SPRINT planning, SCRUM backlog, monitoring team member and team performances by burn-down graphs, daily SCRUM stand-up meetings, and the SCRUM retrospective. As with other agile software development methods, this method best fits to smaller development teams (Sutherland and Schwaber 2011).

The SCRUM meeting is an attempt to follow a project's progress on daily basis. Frederic Brooks (Brooks 1995) published the first edition of his book in 1975 and explained that the planning describes an effort to accomplish a task, but this cannot be used to track the project's progress.

"First, techniques of estimating are poorly developed. More seriously, they reflect an unvoiced assumption which is quite untrue, i.e., that all will go well. Second, our estimating techniques fallaciously confuse effort with progress, hiding the assumption that men and months are interchangeable." (Brooks 1995)

The software development tools offered by major software companies such as IBM, Microsoft, and Hewlett-Packard all support the SCRUM software development method. "In 2011, SCRUM is used in over 75% of agile implementations worldwide" (Sutherland and Schwaber 2011).

SCRUM best fits to those projects where the requirements are created in-house. The successful SCRUM implementation requires continuous customer involvement. It is not a realistic expectation if the requirements are dictated by a client of the IT company.

The experience that the author of this dissertation has had with SCRUM implementation in a full-scale industrial project shows that the SCRUM daily meetings can waste a large amount of time. Furthermore, continuous monitoring of the team members and team performances can create a lot of tension in a troublesome project.

3.3.2 Test-Driven Development

Besides creating Extreme Programming and helping define agile software development methodologies, Kent Beck reinvented the test-first or Test Driven Development (TDD) approach. Sometimes the TDD acronym is translated as Test Driven Design (Beck 2002a).

The TDD approach requires writing test code before writing implementation code, and implementation code is refactored to remove duplicates when additional test code is written. This approach improves test coverage and testing culture (Bulajic and Stojic 2011).

A number of studies and experiments have been accomplished at universities and large software companies, such as IBM and Microsoft, where the primary goal was determining the answer to the question of how effective is the TDD software development method.

Bulajic et al. 2012 (Bulajic et al. 2012), analyzed the results of multiple published research projects and experiments where the primary purpose was to receive confirmation about the claimed benefits and advantages of TDD. This paper analyzed the reliability of the results and reliability of the empirical project's design and participants. The analyzed project accomplished at IBM, Microsoft, and the North Carolina University shows that the TDD methodology is not used strictly, but rather used a hybrid approach where the TDD is combined with requirement analysis and upfront application design.

It is difficult to draw a decisive conclusion regarding the accuracy of the TDD methodology's claims that it improves internal software design, makes further changes and maintenance easier, and uses the same amount of time or less for project development, because the results of empirical studies differ significantly (Bulajic et al. 2012).

3.4 Formal System Development methodology

The Formal Development Methodology (FDM) (Wing 1988) is based on the systematical formal mathematical transformations of requirements into more detailed mathematical representations that are finally converted into an executable program. Wing (Wing 1988) requires that a formal specification "has a precise and unambiguous semantics".

"A precise and unambiguous semantic is given by mathematics usually in the form of a set of definitions, a set of logical formulas, or an abstract model. These three approaches to giving formal semantics roughly correspond to the denotational, axiomatic, and operational approaches of giving semantics to a program". (Wing 1988)

Wing (Wing 1988) further considers a specification executable "if an abstract model of specification is a machine-executable interpreter (like a Prolog interpreter)", and thus provides a list of the authors and languages/project for execution of formal specification, such as Lisp, Prolog, Sasco, Please, and SXL.

The Formal Development Method is used for safety-critical computer systems. The advantage of this method is that defects are eliminated through the process of transformations and verifications where each transformation represents the correct mathematical system and is a true implementation of specification (*So*mmerville, Ian 2001).

The disadvantage of this methodology is that this method requires specialized expertise and there is a lack of significant costs advantages. Parnas (Parnas 1985) in his famous paper about the Strategic Defense Initiative (SDI) describes the limitations of formal system methods:

"We can prove that certain small programs in special programming languages meet a specification. The word 'small' is a relative one. Those working in verification would consider a 500-line program to be large".

Parnas further describes how programs are "often written in programming languages whose semantics are difficult to formalize" (Parnas 1985).

3.5 Unified Software Development Process

The Unified Software Development Process (UP), a case-driven iterative and incremental component-based software development method, architecture-centric and risk-focused, was created by Ivar Jacobsen, Grady Booch, and James Rumbaugh (Leffingwell and Widrig 2000).

The UP software development method defines four development phases, called :

1. Inception,
2. Elaboration,
3. Construction, and
4. Transition.

Each of these four phases can have one or more iterations in which are executed Business Modeling, Requirements, Analysis & Design, Implementation, Test, and Deployment activities. This method uses the Unified Modeling Language (UML) for object-oriented modeling.

Leffingwell and Widrig, describe a road map in the Unified Process method as (Leffingwell and Widrig 2000):

1. The Problem Domain,
2. Stakeholder Needs,
3. Moving Toward the Solution Domain,
4. Features of the System,
5. Software Requirements.

A Problem Domain is identified by Needs, while the Features and Software Requirements belong to the Solution Domain (Leffingwell and Widrig 2000).

The IBM Rational Unified Process (RUP) component-based process is an implementation of the Unified Process (UP). The RUP further refines the UP method and provides a large software suite for supporting and documenting the modeling process.

"The IBM Rational Unified Process (RUP) is a comprehensive process framework that provides industry-tested practices for software and systems delivery and implementation and for effective project management. It is one of many processes contained within the Rational Process Library, which offers best practices guidance suited to your particular development or project need." (IBM Rational Unified Process (RUP) 2012)

The RUP can be considered expensive for small-sized projects and the learning process can be long. The investment in the learning process is lost if a company decides to change its tool or method. RUP is open for integration with other agile software development methods, such as Extreme Programming (Beck 2002), SCRUM (Sutherland and Schwaber 2011), etc. Some programmers consider the RUP method too heavy, although it is possible to tailor solution to one's current needs.

3.6 Microsoft Solution Framework (MSF)

The Microsoft Solutions Framework (MSF) is the implementation of Microsoft's best practice method for delivering software according to specifications, on time and on budget ("Microsoft Solution Framework 3.0 Overview"2003).

Besides the MSF disciplines Project Management, Risk Management, and Readiness Management, the MSF key concept is based on the proven practice and foundational principles that foster open communications, shared vision, learning from experiences, agility, and focus on delivering business values, and team models ("Microsoft Solution Framework 3.0 Overview" 2003).

The MSF Process Model is based on phases and milestones and is a combination of the waterfall and spiral software development methods. The spiral software development model implements an incremental software development model and is a combination of the waterfall and evolutionary software development process. The spiral software development model is focused on project planning, requirement documenting, and risk assessment. The MSF implements an agile approach and delivers the release as early as possible. The MSF Process Model defines the following phases and milestones ("Microsoft Solution Framework (MSF) Overview"2014):

1. Envisioning – milestone Vision/Scope Approved
2. Planning – milestone Project Plan Approved
3. Developing – milestone Scope Complete
4. Stabilizing – milestone Release Readiness Approved
5. Deploying – milestone Deployment Complete

The MSF addresses key software development issues, such as understanding the business problem for a development team, solving problems with internal and external team communications, and dealing with issues related to the requirements "that fail to address the real customer problems, cannot be implemented as stated, omit important features, and/or include an unsubstantiated feature's purpose" ("Microsoft Solution Framework 3.0 Overview" 2003).

The latest version of MSF was released in Visual Studio 2013 and is “an adaptable approach for successfully delivering technology solutions faster, with fewer people and less risk, while enabling higher quality results” (“Microsoft Solution Framework (SDM) Overview” 2014).

Besides addressing software development issues and documenting and tracking outputs from each phase, the MSF addresses issues related to the deployment of a solution to the production environment.

3.7 Prototyping

Prototyping is a well-known practice in the software industry. Wiegers (Wiegers 2003) defines a prototype as “a partial or possible implementation” and describes three major purposes: requirements clarification, design alternatives exploration, and growth into the ultimate product. Wiegers describes numerous different types of prototype (Wiegers 2003):

1. Horizontal prototypes (behavioral or mock up), focused on the user interface and able to show limited workflow and navigation without implementing real functionality or touching architectural issues,
2. Vertical prototypes (structural prototypes or proof of concept), working through layers and used as proof of concepts of the architecture and design,
3. Throwaway prototypes,
4. Evolutionary prototypes,
5. Paper and Electronic prototypes, which are cheap prototypes made on plain paper, sticky notes, etc.

Davis (Davis 2005) provides a comprehensive discussion about software prototypes.

Sommerville sees prototyping as a requirement verification technique (Sommerville 2001). Sommerville (Sommerville 2001) describes the following prototype categories:

1. Throwaway prototyping,
2. Evolutionary prototyping.

Sommerville compares prototyping to the evolutionary software development method; “prototype is therefore part of the requirements engineering process. However, the distinction between prototyping as a separate activity and mainstream software development has blurred over the past few years. Many systems are now developed using an evolutionary approach where an initial version is created quickly and modified to produce a final system” (Sommerville 2001).

Even the Generalized Requirement Approach, the solution proposed in this dissertation, can be considered a prototyping, but there are significant differences that are presented in this dissertation. The most remarkable difference is the automatic generation of the source code without manual programming.

3.8 Application and Code Generators

Application and code generators create source code files, SQL statements, XML files and configurations, and application software templates. The source code can be generated by:

- Integrated Development Environment (IDE)
- Framework
- Language
- 4GL application
- Tool

The modern design combines IDE and a framework, and besides providing editors, compilers, builds facilities, and debuggers, it provides classes, libraries, and code able to generate application templates, classes and methods, XML files and configurations; do code refactoring; and execute or interpret generated code. Examples of the modern IDEs that combine IDE and a framework in the same software products are IBM Eclipse ("Eclipse Documentation" 2014) and Microsoft Visual Studio ("Get Started with Visual Studio" 2014).

The IBM Eclipse and Visual Studio are open for integration and provide a plug-ins application interface for adding features and frameworks developed by third-party software vendors. An example is the "Eclipse SCOUT" ("Eclipse Documentation" 2014) plug-in that enables visual design of the user interface in Java. The code generated by Eclipse and Visual Studio targets programmers and developers who need to improve productivity and automate development based on custom-designed templates.

The generated code is a template that needs to be updated with manually written code to satisfy requirements written in the Requirement Specification document. The generated and updated code validates the Requirement Specification against an application code, and is not used for validating a customer requirement before creating the Requirement Specification document.

Languages also exist that are able to generate application software; such languages can be divided into (Tse and Pong 1991):

- Textual language – based on natural language or "formal like programming languages",
- Graphical language –consists of a limited number of understandable symbols,
- Hybrid language – combination of the previous two, graphical language for presenting an overview and textual language for detailed descriptions.

The Textual languages based on the Natural Language Processing (NLP) belong to the field of Artificial Intelligence (AI), and are searching for algorithms “that allow computers to process and understand human languages” (“The Stanford Natural Language Processing Group” 2014).

The natural language is subject to different interpretations and can cause ambiguities. “Standard English prose is not suitable even for specifications which are processed manually. Languages that have a better defined syntax and slightly more restrictive semantics would therefore be preferred. These languages are more formal in nature and resemble a programming language or a mathematical language” (Tse and Pong 1991).

One example of a formal specification language is the Requirement Specification Language (RSL). “The purpose of RSL is to describe precisely the external structure of a system comprised of hardware, software, and human processing elements. To overcome the deficiencies of informal specification languages, RSL includes facilities for mathematical specification” (Frincke 1992).

Another example of a formal specification language is the Specification and Description Language (SDL). SDL is used for real-time telecommunication applications, and the development and simulation of the complex event-driven communications systems (“Improve SDL software development for communications systems” 2014).

The formal specification languages are based on the mathematical analysis and algorithms. While mathematical techniques are widely accepted and used in other engineering industries, such as mechanics, civil engineering, and electrical engineering, the mathematical techniques are not widely used in industrial software development (Sommerville 2001).

Sommerville (Sommerville 2001) pointed out that software development is based on the three levels of specifications: the user requirements specification (most abstract), the system requirements specification, and the software design specification (most detailed). Formal specification languages are generally supporting processes that are “somewhere between the system requirements specification and software design specification”.

Tse and Pong (Tse and Pong 1991) emphasized the importance of the formal framework and precise notation with unique interpretation. “In order to eliminate the problems of ambiguity during the construction and implementation of a target system, the requirements specification should be expressible in a precise notation with a unique interpretation. A formal framework must, therefore, be present. It helps to reduce the probability of misunderstanding between different designers. At the same time, automated tools based on the formal framework can be used to validate the consistency and completeness of the specification” (Tse and Pong 1991).

Graphical language enables visual modelling and helps generate textual system descriptions, source code, scripts, and applications. Visual Modeling is often delivered as part of the IDE. For example, the Eclipse Modelling Framework (EMF) is integrated in the Eclipse IDE.

“The Eclipse Modeling Framework (EMF) is a modeling-framework and code-generation facility for building tools and other applications based on a structured data model, from a model specification described in XML. EMF provides tools and runtime support to produce a set of Java classes for the model, a set of adapter classes that enable viewing and command-based editing of the model, and a basic editor”. (“Eclipse Documentation” 2014)

The IBM Rational® software development platform delivers visual modeling tools based on the UML 2.0 as separate software suites, Rational Web Developer and Rational Software Modeler, or as an integrated part of the Rational Application Developer and Rational Software Architect (“Discover IBM Rational visual tools for application development” 2014).

IBM Rational software products and Microsoft Visual Studio visual modeling are based on the implementation of the UML language.

Bonitasoft, Inc. developed “Bonita BPM Studio” visual modeling software for Business Process Modeling (BPM). Bonita BPM Studio is used for analyzing, visualizing, and modeling of the business process (“Discover Bonita BPM 6” 2014). Even Bonita BPM Studio does not generate code—it uses visual modeling to create and execute applications that can be used for business process demonstration, analysis, and improvement. The primary users of the BPM software are business analysts and managers. The authors did not have the experience of using BPM tools during the requirement negotiation process, but trend analyses from Gartner Group and Forrester Research predict that BPM use will significantly increase by 2017 and 2020, respectively (Hamby and McConnell, Mac (2012).

Hybrid languages support the graphical languages using textual description. “Although graphical languages are better than textual languages in presenting an overview of a complex situation, textual languages are regarded as better tools for detailed description. Although formal languages have precise semantics, their meanings are often explained through natural languages. We need, therefore, a language which exists in more than one format” (Tse and Pong 1991).

The Fourth Generation Language (4GL) is a tool for rapid application development. The 4GL’s intention was to improve the productivity of developers and programmers and reduce the effort needed for creating application software. The new application software is created by changing configurations and properties of the predefined set of the application controls and objects. The workbench that implements the drag-and-drop feature speeds up development and generates source code and application during the build procedure. Oracle in the mid 1980’s introduced SQL Forms, considered to be "powerful database application development tools" ("Oracle Application Express SQL Forms" 2014).

Microsoft developed Visual Basic at the beginning of 1990s ("Visual Basic resources" 2014). Oracle Java technology offers JavaServer Faces (JSF) "for building server-side user interfaces" ("Java Server Faces Technology" 2014). Today SQL Forms, Visual Basic, and JSF are not promoted as 4GL applications, but delivered features can be described by 4GL application features that provide rapid application development environment, such as generating source code and applications based on the changing predefined controls and components parameters; using drag-and-drop features; visual modeling of components and interfaces; and easy integration with back-end systems such as what's found in databases.

The source code can be generated by using specialized tools. The tool in this case is an executable software program that is able to generate source code from the configuration that is usually expressed as an XML file. One example of such tool is wsdl.exe for generating a proxy class for XML Web Service client ("Web Services Description Language Tool (Wsdl.exe)" 2014). The wsdl.exe is able to create a proxy class in different languages. The target language is possible to specify by changing the wsdl.exe "/language" parameter ("Web Services Description Language Tool (Wsdl.exe)" 2014).

The software products presented in this chapter are targeting programmers and developers. The presented software's purpose is to support code and scripts generation based on custom-designed templates rather than support the requirement specification process.

Sommerville (Sommerville 2001) pointed that software development is based on three levels of specifications— the user requirements specification (most abstract), the system requirements specification, and the software design specification (most detailed), and formal specification languages generally support processes that are "somewhere between a system requirements specification and a software design specification".

While the software products presented here can reduce the effort necessary for creating application software, the use of these software products during the requirement negotiation process is limited by the tools' complexity and the need for a certain level of competence before the software product can be effectively used. The probability that an end-user will understand the software product and technical platform is marginal; using a software product during the requirement negotiation process that the end-user does not understand can cause more harm than good.

This dissertation proposes a solution that combines several presented features, such as code and application generation and structured requirement description, but is adapted to the user's language.

3.9 Requirement Management Tools

On the market are currently available several tools for Software Requirement Management (SRM). Reviewing each individual tool can be a waste of time; therefore, this chapter contains only reviews of the tools delivered by leading IT companies, such as Microsoft, IBM, Hewlett Packard (HP), and Borland.

Hewlett Packard recently acquired a Test Director from Mercury Interactive Corporation and changed its name from Test Director to HP Quality Center (HP QC). Requirement Management is one of the most important parts of the Application Lifecycle Management (ALM) tools. "The HP Quality Center supports requirements definition and management, release and cycle management, test planning and scheduling, defects management and reporting—all within a single platform with complete traceability driving collaboration between business analysts, QA, and development teams" ("Quality Center Software" 2012).

The HP QC enables requirement description, requirement breakdown to sub-requirements, and links of requirement to implementation through the work packages definition. It also defines software releases, creates and links test cases to one or more requirements, executes test cases in the Test Lab, and creates Defects. Cross-linked references and reporting is supported by dynamically creating conditional statements that help to quickly navigate from requirement to test case and defect. Reports can be textual and graphical. Graphical reports helps visualize the information about work already done and the remaining work. Reports can quickly discover requirements that are uncovered by test cases. HP QC is a team collaboration platform and the Web interface enables the project team to access and change requirements, to add comments, and to inspect and execute test cases.

While HP QC offers an integrated platform for requirement management, release management, test management, and defect management, IBM provides different tools for requirement management, test and defect management, and project management.

"However, IBM provided multiple solutions in some of these areas, leading to confusion about what exactly each of these tools was supporting and how they all worked together. That confusion has largely dissipated with IBM's current ALM offering. Not only has IBM continued development of its strong suite of products, but it has also stitched them together in a more coherent way." (Grant et al. 2012)

IBM Rational tools are integrated in the IBM development tools—for example, Rational Application Developer (RAD)—and this development environment enables visual modeling by using UML, which, according to IBM, accelerates development. IBM RAD is generally supportive of Java technologies, and Web and mobile application development, Java EE and SOA, as well as C/C++ languages.

While HP QC links requirements to test cases and defects, IBM Rational Requisite Pro links requirements to use cases, and use cases to the test case.

Borland Caliber provides the possibility to visualize the user's conceptual idea (called the user story) through storyboarding, prototyping, and simulations. Borland Caliber supports integration to Rally and Microsoft Team Foundation Server.

Rally is, according to Forrester Research, a leader in Agile/Lean tool providers, and these tools "are optimized for Agile planning, project management, status reporting, and other actions that happen within and outside sprints" and can be "less attractive for non-agile than other general-purpose ALM tools" (Grant et al. 2012).

The Microsoft Team Foundation Server (TFS) is a Microsoft solution and is a part of the Visual Studio development environment.

"The Visual Studio Team Foundation Server 2012 (TFS) is the collaboration platform at the core of Microsoft's application lifecycle management (ALM) solution. TFS supports agile development practices, multiple IDEs and platforms locally or in the cloud, and gives you the tools you need to effectively manage software development projects throughout the IT lifecycle." ("Team Foundation Server" 2012)

The TFS Version 2012 offers new features and enhancements in Visual Studio 2012, such as better support for SCRUM agile development, illustrating requirements with storyboards, engaging stakeholders by frequent and continuous feedback, modeling applications by creating dependencies graphs, testing with Microsoft Test Manager, and many other assets that support mobile development, debugging, and code visualizing.

"Microsoft deserves recognition for understanding how central collaboration is to ALM. While the "M word" management is part of the ALM acronym, ALM initiatives frequently fail because they emphasize control over collaboration." (Grant et al. 2012)

The purpose of the tools presented in this chapter, besides requirement management, is project management and team collaboration support. These tools presented here enable requirement description and storage, define the columns and fields and state transitions, and provide searching and filtering, traceability and reporting, as well as team collaboration through Web interface.

Specifying requirements takes time this time can be wasted if the requirement is not clearly specified or the requirement's purpose is not clearly explained. The presented tools are not able to generate source code and executables to validate a requirement's description.

"Many IT organizations expect their requirements management tools to measure or even to improve the quality of their requirements. But requirements management tools are agnostic about requirements contents: They store, associate, and form requirements without any respect to their quality". (Schwaber and Sterpe 2007)

3.10 Requirement Verification

The software development methods analyzed in this chapter assume that the first step in the software development process is dedicated to Requirement Engineering.

Requirement Engineering is described as a process of requirement analysis, elicitation, specification, and verification (Wiegers 2003).

The goal of the requirement verification process is confirmation that a requirement is specified according to a good requirement definition practice. A good requirement definition practice means that the requirement description is consistent, complete, correct, verifiable, traceable, and testable. The business requirements expressed by customer language often need to go through a requirement breakdown procedure to satisfy the good requirement specifications.

“It would be wonderful if the human brain was capable of understanding the whole, without instinctively dividing everything into its parts, and if human knowledge was capable of providing laboratories and equipment for such kinds of massive research. Reality teaches us that the human capability of understanding and interacting with complex systems is limited. Because of this, to be able to understand and control a process, humans must divide it into a lesser degree of the whole so it can be analyzed and explained, and then group and recombine the process to its greater whole that is concatenated by theories and laws”. (Bulajic et al. 2013b)

The requirement verification requires that the requirement specification is already written. Sommerville (Sommerville 2001) describes requirement verification as an iterative process that occurs between requirement specification and verification of requirement specification.

The requirement verification is accomplished by a formal inspection of the requirement specification document usually using small teams. The inspection can be supported by developing functional test cases and specifying acceptance criteria (Wiegers 2003).

With the Rational Unified Process (RUP) implementation of the Unified Process (UP), verification is accomplished with a traceability matrix. In this matrix, requirements are linked to features, the features are linked to Use Cases, and the Use Cases are linked to Test Cases. If any of these links are missing, the requirement is not considered properly verified.

Linking requirements described by the User Story to Use Cases, and linking the Use Cases to Test Cases is a common verification technique that is used in iterative and incremental development methods, such as agile methods. The verification is based on the peer review techniques and inspection of the requirement documentation. The agile approaches most often use the User Story as a requirement description and from the User Story develop a number of Use Cases and Test Cases. The inspection process should confirm that the User Story requirements are covered by Use Cases and Test Cases.

Despite that the inspection technique, traceability matrix, and model drawings can improve requirement understanding, they are still manual verification techniques based on the text and graphics description. A business requirement verification established when requirements are gathered by using text and graphics can be slow, error prone, and expensive.

3.11 Efficiency of Existing SDM

Despite the existence of so many software development methods, the software development success rate is getting worse, according to Standish Chaos Report 2009. The 2006 Standish Group reported that 35% of the projects were successful, 46% challenged, and 19% failed, and in 2009 they reported that 32% were successful, 44% challenged, and 24% failed (Eveleens and Verhoef 2010).

The aim of this research work is to improve the project success rate.

All further discussion in this dissertation is limited to the traditional Software Development Methodology (SDM), because the traditional Software Development Methodology process structure is implemented in the sequential software development methods, such as the waterfall method, and also in the iterative and incremental software development methods, such as the agile software development methods.

4 Traditional Software Development Method (SDM)

The current software development methods, regardless of whether it is sequential, iterative and incremental, or evolutionary, all follow a traditional Software Development Method process structure. The software development process begins with requirement analysis and must go through system architecture and design before coding and testing can start. The customers can validate the development process result whether or not the customer requirements will be satisfied at the end of the development process. The Traditional Software Development Method is described in Figure 2:

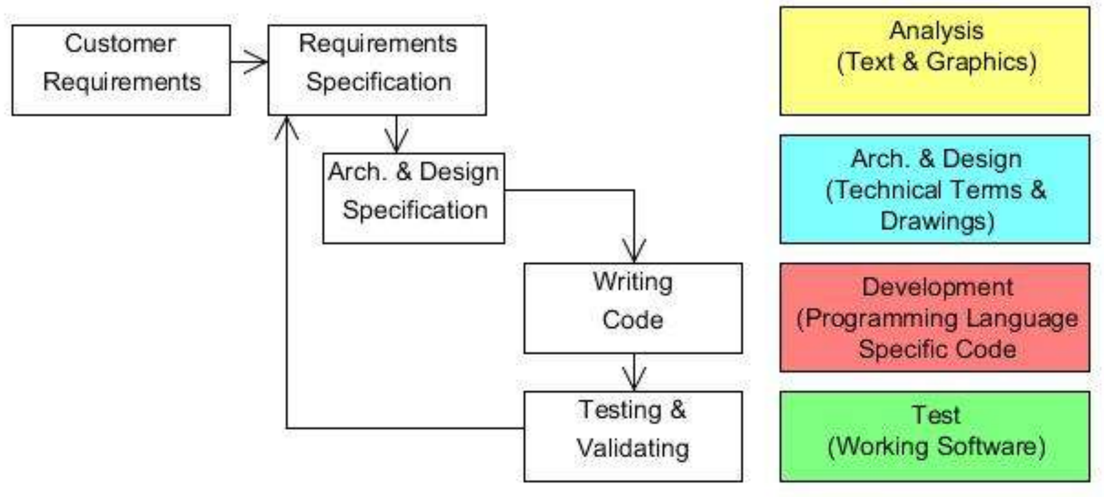

Customer Requirements
Requirements Specification
Arch. & Design Specification
Writing Code
Testing & Validating
Analysis (Text & Graphics)
Arch. & Design (Technical Terms & Drawings)
Development (Programming Language Specific Code
Test (Working Software)

Figure 2 Traditional Software Development Process

An idea about a new business product is often obscure, and described using general terms that contribute to common misunderstandings. The requirements are collected during the Analysis phase and described by text and graphics. Requirement verification, in the event when requirements are gathered using text and graphics, is a slow, error-prone, and expensive process. Misunderstandings and omitted requirements result in revisions and will increase the project's costs and delays.

Although it is common knowledge that written texts as well as graphics are ambiguous and subject to different interpretations, the Requirement Specification is used as a reference document during the software development process. A Requirement Specification is not a guarantee that requirements are properly understood. At this moment during the process, misunderstandings are not yet visible.

The Architecture & Design phase can use specific technical terms and graphics. The architectural drawings and descriptions can be obscure even for people who work in the same company and may require additional explanations from the authors.

In the Development phase the requirements are described by code and syntax that is specific for particular programming languages. The code is translated to even more obscure binary code and executables.

The executables created in the Development phase are used during Testing & Validation process to validate the Requirement Specification. At this point in the process, the customer can see if implementation satisfies his needs he expressed at the beginning of this process with text and graphics. It is only now that the design team will learn whether they have a problem.

This process can be improved by introducing requirement demonstration as early as possible to avoid wasting time and resources on the implementation and modification of misunderstood requirements.

5 Generalized Requirement Approach (GRA)

The Generalized Requirement Approach (GRA) proposes a new methodology to the business software development process and is focused on the validation of a business requirement during the requirement negotiation process. While the current software development process validates business requirement at the end of the coding process, this method implementation offers business requirement validation during the requirement negotiation process.

The following features describe the GRA method:

1. Requirements are described via customer language and stored in the structured text format
2. Source code is generated from a requirement description without manual programming

3. Working software is demonstrated during the requirement negotiations process

Figure 3 illustrates the GRA method:

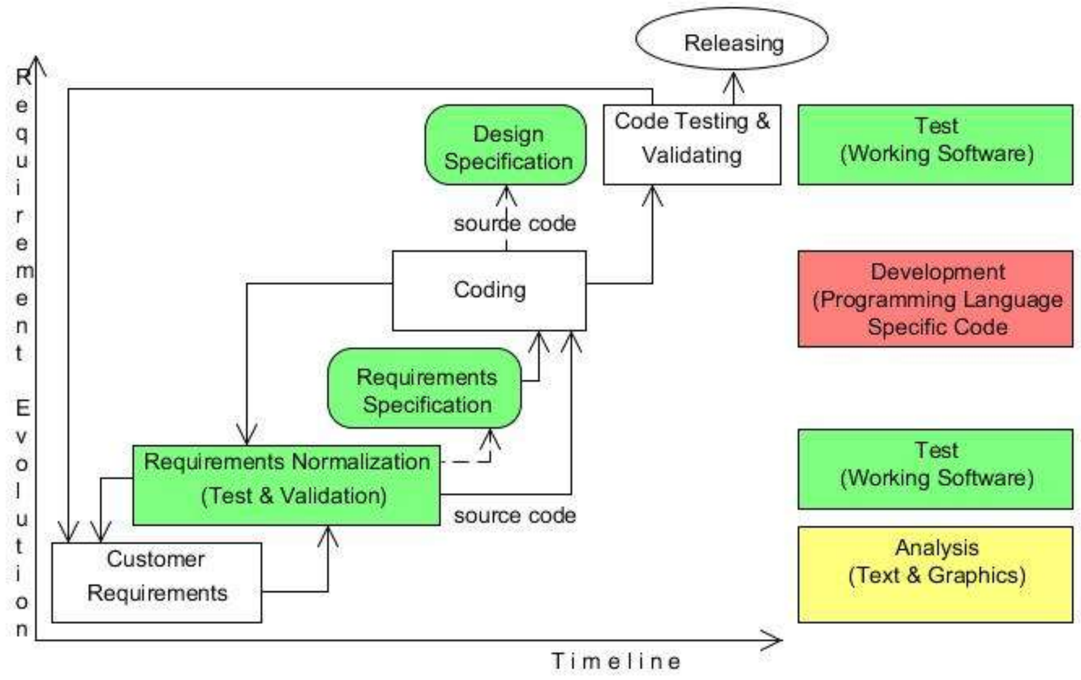

Releasing
Code Testing & Validating
Design Specification
source code
Coding
Requirements Specification
Requirements Normalization (Test & Validation)
source code
Customer Requirements
Test (Working Software)
Development (Programming Language Specific Code
Test (Working Software)
Analysis (Text & Graphics)
Requirement Evolution
Timeline

Figure 3 Generalized Requirement Approach (GRA) Overview

The GRA assumes that customer requirements are described by a language that may be converted to a structured text format. This is true in most cases for a functional business requirement.

Before translation to the Requirement Specifications, the customer requirements must go through a Requirement Normalization process. This Requirement Normalization process is responsible for:

- Describing requirements with a sufficient level of details by using customer language and storing it in the structured text format,
- Demonstration of requirements by generating source and executable code from the requirement description without manual programming.

The Requirement Normalization process is considered complete when the requirement is possible to describe with a sufficient level of details from which it is possible to generate source code and build executables. There is no limitation of how detailed the customer requirements will be described during Requirement Normalization phase before continuing to next phase, the Coding phase.

The Requirement Normalization is the GRA method’s driving force during the requirement negotiation process. The outputs from this process are:

- Requirement Specification,
- Source Code,
- Test Cases, if test cases are created during the requirement documentation process.

The Requirement Specification is used in the Coding phase and needs to be updated by implementation-specific solutions, comments, and issues. It is assumed that architecture and design activities are accomplished during the Coding phase. A direct update of the Requirement Specification is not recommended by the GRA because Requirement Specification is generated by the GRA. The Requirement Specification should be updated through Customer Requirements and Requirement Normalization processes.

The source code generated in the Requirement Normalization phase can be used in the coding phase for further development. If the Coding phase is using generated source code, then the Coding phase is responsible for code optimization, implementation of non-functional requirements, and the creation of the production code version.

The Coding phase can write source code from the beginning and use generated source code for requirement understanding and testing purposes.

The output from the Coding phase results in source code and executables and these are validated in the Code Testing and Validating phase. The Code Testing and Validating phase corresponds to the Test phase in the traditional software development method.

The Requirement Normalization involves implementation of the GRA method. The GRA method strongly depends on this implementation, which is the tool that enables the Requirement Normalization process. This application process is called the GRA Framework (GRAF), and besides its documentation purpose, the GRA Framework contains classes and libraries that are used for automatic code generation, which is one of the preconditions for the Test & Validation process.

6 Generalized Requirement Approach Framework (GRAF)

“Implementing an idea can be a challenge. The best example is an idea about human rights. This idea is simple and easy understandable, but implementation is not properly accomplished even in the most developed countries in this world.” (Aleksandar Bulajic)

The Generalized Requirement Approach Framework (GRAF) implementation was created to support the GRA method. The GRA Framework contains objects, classes, and libraries responsible for guiding a user to provide detailed requirement specifications that are sufficient for generating source code and executables. The GRAF is responsible for implementation of the GRA features.

It is recommended that the GRA Framework be employed as an interactive, event-driven application. Interactive event-driven applications, besides visualizing data through a User Interface (UI), enables the execution of the specific data processing based on the external stimulus; for example, a mouse click on an action button, or the execution of the processing based on a specific occurrence, such as a data-changed event. Both these features can be important during requirement negotiation to visualize data and execute data processing. Even in cases where the applications are not interactive, visualizing data and executing processing is necessary during the requirement negotiation process.

Figure 4 illustrates the GRA Framework's high level design:

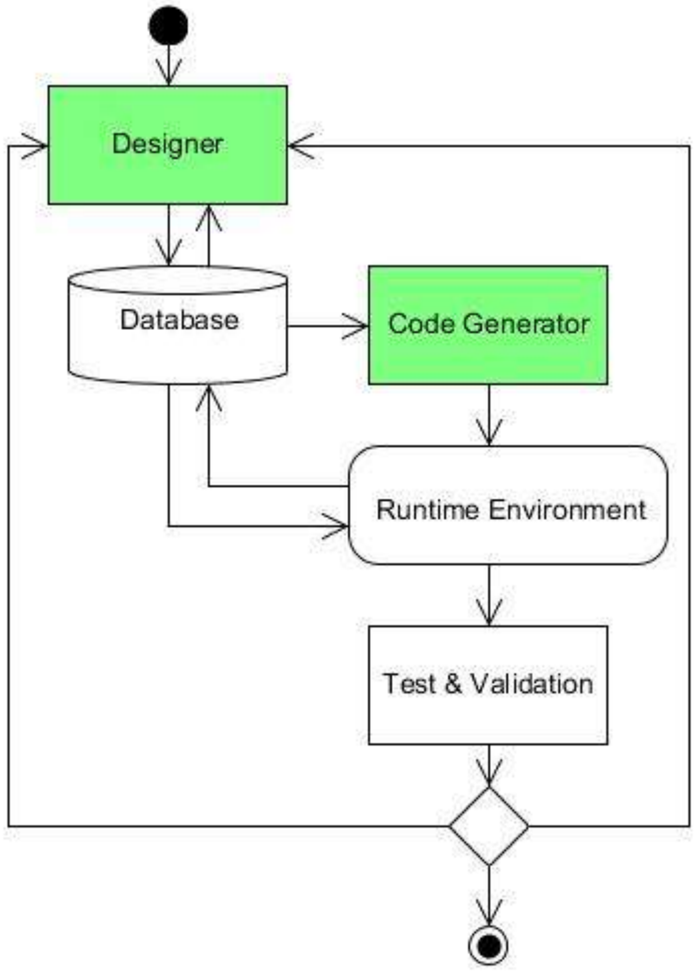


Figure 4 The GRA Framework Design Overview

The designer is responsible for storing the requirement description in the structured text format in the database. The designer is also responsible for guiding a user to specify a sufficient amount of details. A Code Generator is responsible for generating source code by using structured text data stored in the Database. Source code is generated in a standard programming language, for example, C# or Java. The generated source code is executed in the Runtime Environment. The requirements are validated in the Test & Validation process. If the requirement validation does not satisfy the user's expectation, the process can be repeated and returned back to the Designer.

While method features are generally valid and are used as guidelines and recommendations, the utilization of the method features can be implementation-specific. Each implementation can be based on the different object types. The GRA Framework used in this thesis identifies the following groups of objects that are applied by a Designer during the requirement negotiation process:

- Objects responsible for requirement-documenting the User Story, Requirement, Use Case, Test Case, Project, Component, Transaction and Defect objects. The information stored in the attributes of each of these objects is not used for generation of source code,
- Objects responsible for storing data in a structured text format that are used to generate source code: Forms, Data Sources, Application Objects, and Interfaces.

Each GRA Framework object is mapped to one or more corresponding database entities that are used for storing data in the structured text format and for retrieving data when the GRA Framework needs it.

The following is a description of each of the objects responsible for requirement documenting:

- User Story – describes customer requirements by using a common User Story template "As <role> I need/want <goal> because of <benefits>". The User Story describes a customer's business need and interest, and before implementation usually needs to be broken down into a formal requirement description
- Requirement – represents the formal requirement description according to the good requirement description practice. The good requirement definition practice means that the requirement is consistent, complete, correct, verifiable, traceable, and testable
- Use Case – describes the steps and expected results of each step during the interaction between the stakeholder and application software. Use Cases are usually created from the User Story and Requirement
- Test Case – describes the steps and data that are used for testing a particular application software feature. The Test Case can be created from the User Story, Use Cases, and Requirements

- Project – describes the general information of the assignment, such as the project name, project description, project business purpose, project owners, project start and end dates, contract ID, and estimated effort. The project groups together all project-related information

- Component –used to structure project-related information into sub-groups

- Defect – stores information about defects discovered during the software development process

The objects responsible for storing data in structured text format are business application building blocks. The following text describes each of these objects and the context in which the objects are used:

- Forms – describes entry fields and other predefined Graphical User Interface (GUI) controls, and enables the user to enter data, assign actions to data, and process data with a mouse click

- Data Sources –responsible for creating database tables and relations

- Application Objects – objects responsible for backend or batch job processing

- Interfaces – objects that are at the same time Application Objects, but for here are a specific communication with sources of data external to the application

Details about Code Generator are described in the Figure 5, in the Chapter 6.2 "Generate Source Code without Manual Programming".

6.1 Document and Store Requirements in the Structured Text Format Described by Customer Language

Storing requirement descriptions in the structured text format is the precondition for automatic source code generation. The requirement description is guided by a set of predefined objects and their attributes. Each object stores data about a closely related class of objects. For example, the User Story can be generally described by a common template: "As <role> I need/want <goal> to achieve <benefit>", or by using a definitive documenting template, such as the Five Ws template (Who, When, Where, What, Why).

Documenting requirements in the structured text format as they are described by the customer's language is illustrated by the Form example. The Form is used for customer interactive communication with the application software. While each form can have different names, fields, field' types, and lengths, and each field can be presented by different control types, each form can generally be described by using the same general terms, such as the form's name, field name, etc. The form description can be generalized by following a textual description structure:

- form name,

- field name,

- data type,
- length,
- number of decimal places,
- control type,
- action type.

The Form's description is used to describe various forms, and each form can have different fields. For example, PRODUCT and PAYMENT forms can have different fields and a multiple number of fields.

The Form name as well as the name of each form field can be described by customer language. For example, a form name can be PRODUCT and the fields' names can be PRODUCT_NAME, PRODUCT_DESCRIPTION, PRICE, and QUANTITY. Another example of a form name can be PAYMENT, and the field names can be CREDIT_CARD_TYPE, CREDIT_CARD_NUMBER, EXPIRATION_DATE, and CONTROL_CODE. The customer understands the business meaning and context of the forms where these names are/can be used.

6.2 Generate Source Code without Manual Programming

The GRA method assumes that the source code is generated without manual programming. Figure 5 illustrates how this feature can be implemented:

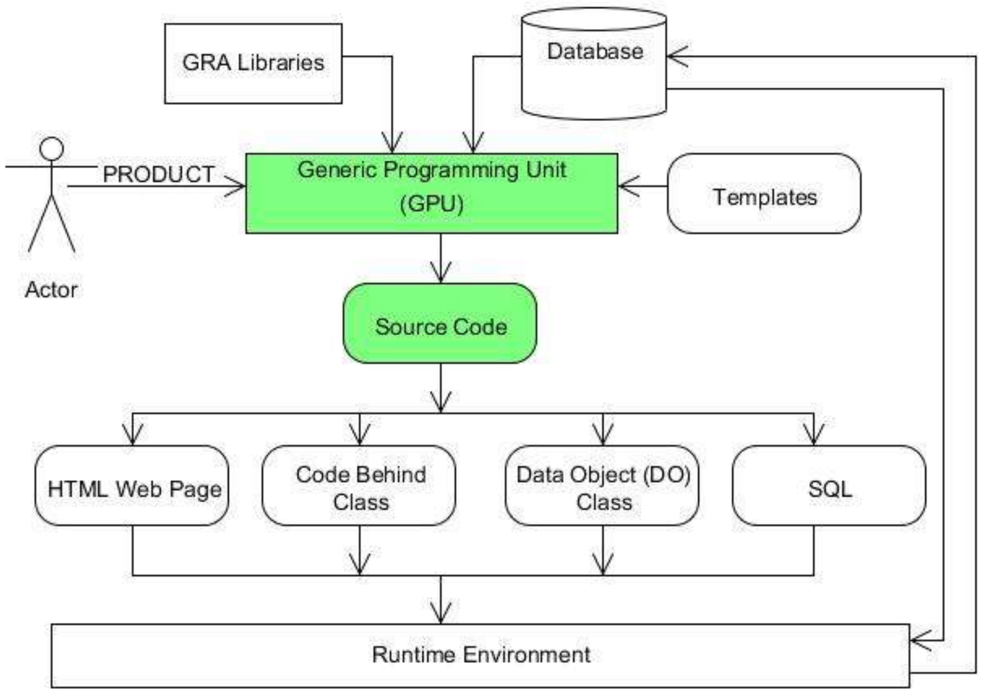


Figure 5 Generalized Requirement Approach Framework Source Code Generations

The structured text descriptions are stored in the database tables. The source code is generated from the structured text descriptions using the GRA Libraries. The GRA Libraries contain the parameterized methods and templates. The templates are parameterized statements expressed by valid syntax that is supported by a particular programming language. The template's contents are dictated by implementation technology. In this particular implementation, Microsoft ASP.NET technology is used and the templates are dictated by the ASP.NET supported languages and by the ASP.NET technology design and architecture. In situations where the GRA Framework is implemented by using Java and Java Server Pages (JSP) technology, the templates shall be adapted to the Java language syntax as well as to the JSP technology design and architecture.

The methods and templates are adapted to requirement specifics, and inserted in the generated source code. Therefore, the methods and templates are the building blocks to create new source code. The process of source code generation is initiated externally from an Actor by sending a name of the object that needs to be generated.

The Generic Programming Unit (GPU) is a computer code that generates source code by using structured text descriptions stored in the Database, along with the GRA Library methods and Templates. In other words, the GPU reads the data stored in the Database for each particular object and generates the source code according to structured text descriptions by using the GRA Libraries and Templates.

The outputs from the GPU are HTML Web Page, Data Object Class, SQL statements, and Code-Behind Class. Code-Behind Class is an ASP.NET page code that is contained within a separate class file for clean separation of HTML code from presentation logic ("ASP.NET Code-Behind Model Overview" 2013).

The Data Object Class is responsible for data mapping from an object to the persistent data source and from persistent data source to an object. The Data Object Class is a part of the Data Access Object (DAO) design pattern implementation. The DAO Design Pattern is used for separating object persistence and data access logic from a particular persistence mechanism or API (Bulajic 2011).

The generated SQL statements are used in the implementation of create, read, update, and delete (CRUD) database operations.

The Runtime Environment is responsible for execution of the generated source code. The GRAF implementation described in this dissertation supports ASP.NET application types and the Runtime Environment requires installation of the Microsoft .NET Framework and Common Language Runtime (CLR) to be able to execute generated source code. The CLR is included in the Microsoft .NET Framework installation.

The ASP.NET compiles Code Behind Class on the fly when file is new or updated, and the ASP.NET detects updates when a class file is requested through a timestamp change (“INFO: ASP.NET Code-Behind Model Overview” 2013). Therefore it is not necessary to compile and build generated source code before an execution. The ASP.NET compiles each class to an object code when a class is requested, and enables Web page access to the object properties and event handlers.

The process of generating source code is illustrated on a generating source code for PRODUCT form. The example is generated according to the Microsoft ASP.NET specific implementation requirements, and for this example uses the Microsoft ASP.NET specific templates and libraries. The process of generating source code, illustrated in the Figure 5, is described further in the Chapter 14 “Appendix B – Generating Source Code”.

6.3 GRA Framework Generic Methods Implementation Details

This chapter describes methods that are specific for Retail Store applications. In the GRA Framework, the Retail Store specific methods are implemented as generic methods that can solve classes of similar problems, as for example, mathematical operations on the internal variables or mathematical operations on the SQL data. While the common method design is focused on solving a particular programming problem where the variables and affected objects are known in advance, the Generalized Requirement Approach requires a design that can solve a related class of programming problems. Solving a class of related programming problems inside the same method is achieved by parameterizing—by dynamically changing parameter values during method execution. The parameters are combined by a segment of code that adapts processing according to the parameter values.

The GRA Framework generic methods are identified during the development of the Retail Store application, a fictive E-Commerce application. A detailed description of the Retail Store application development is in Chapter 15 “Appendix C – Retail Store Example”.

Implemented in the GRA Framework are the following generic methods:

- mathFormula – math operations on the numeric data stored in the application internal memory,
- sqlMathExpression – for calculation based on the data stored in the SQL tables,
- addRowToDatasource – adds current row data to the output data source,
- updateRowToDatasource – updates row in the database by using current object data.

The method identification and development are the author’s own interpretation and it is implemented as such. The implementation effort was halted when the implemented methods were able to support the Retail Store application requirements. The test of the implementation was focused on proving that the solution works, and thus in this implementation of the GRA Framework, only the errors are corrected that prevent application execution or display incorrect operation results.

Additional requirements for this application are described by the RetailStoreProject User Story, BuyerStory User Story, and SalesDepartmentStory User Story in Chapter 7 “GRA Framework Validation”. Figure 6 describes the purchase process and related calculations, and is based on the requirements as described in the BuyerStory User Story and SalesDepartmentStory User Story:

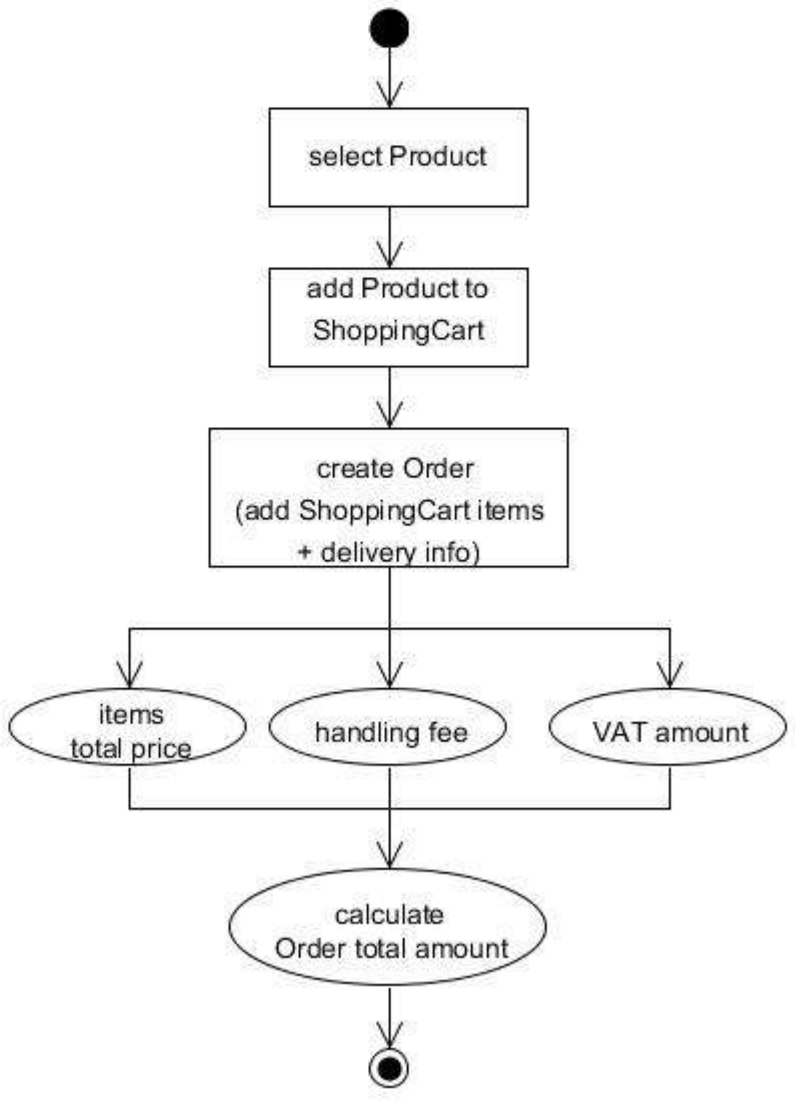

select Product
add Product to ShoppingCart
create Order (add ShoppingCart items + delivery info)
items total price
handling fee
VAT amount
calculate Order total amount

Figure 6 Retail Store Product Purchase Process

The purchasing process starts with selecting a Product and adding the Product to the Shopping Cart.

The Shopping Cart items are used for creating an Order. Besides calculating the selected product item's total price, the Order needs to calculate the VAT amount and total price. The total price and VAT amount calculations are based on the item's total price and handling fee. The Order total amount is a sum of the item's total price, handling fee, and VAT amount.

In the event-driven application, method execution can be assigned to a specific application event, for example, a mouse-click event or text-changed event. With the ASP.NET and HTML, the event is assigned to the predefined set of controls that are part of the HTML and ASP.NET technology, such as action button controls or input controls. The GRA Framework developed in this dissertation solves the method execution issues by using event-driven features built inside the ASP.NET and HTML controls, and assigns method execution during generation of source code according to the requirement description.

While creating generic methods can be a challenge for less experienced developers, the experience collected during the development of this framework shows that it becomes easier to write new generic methods as the code basis increases. Already created generic methods can be used to form new generic methods. This approach requires using abstract classes, abstract data types and interfaces, loose coupling, and internal implementation details need to be hidden, which fits well to the Object-Oriented (OO) basic concepts.

Design patterns (Gamma et al. 1995) can be a great inspiration for designing and writing general purpose methods. Refactoring techniques (Fowler et al. 1999) can be used to learn about improving code reusability. Analyzing design patterns such as Data Access Object, Abstract Factory (Bulajic and Jovanovic 2012), MVC pattern, and Strategy Pattern can be useful for designing general purpose methods.

6.3.1 mathFormula

The mathFormula generic method is used for calculations that can be expressed with implementation language notation and available math functions, and is executed on the numeric data stored in the application internal memory. Besides solving the Retails Store specific calculation problems, this method can solve any other mathematical calculation problem that can be expressed using basic mathematical operators—addition, subtraction, multiplication, division—and by parentheses to manage the order of operations.

This method enables storage of the mathematical operations sub-results in the internal variables in order to use the sub-results as mathematical operands in the next calculation.

Figure 7 illustrates the use of sub-results:

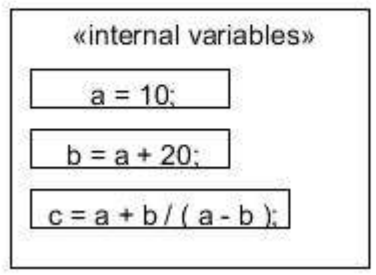


Figure 7 mathFormula

In the Figure 7, an operand is used in the b value calculations, and a and b are used in the c math operations. The a, b, and c variables should exist when calculations need to be executed.

Describing the operands and math operations is the responsibility of the requirement negotiation team. Operands are stored in the requirement description together with the math operations.

The GPU is responsible for reading the requirement description, defining the variables, and assigning math operations. Because the math operations are based on the basic set of the math operators that are available in the C# language, the GPU does not need to use any GRA Libraries or Templates. Each math expression is assigned directly to the variable. Based on the example described in the Figure 7, the GPU generates the following code:

```
public int a;
public string handlingfee;
public string vatamount;

a = 10;
b = a + 20;
c = a + b / (a - b);
```

The result of each of calculations is stored in the corresponding variable: a, b, and c.

This approach enables the creation of complex mathematical calculations by storing sub-results in the internal variable and using it in the next calculations as operands. The number of variables is not limited by this GRA Framework implementation and is a subject of limitations related to the implementation technology.

In the Retail Store application, the formula for calculating the Order total amount is used:

itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100

The above formula adds the Handling Fee to the Items Total and then adds the VAT amount that is calculated as percentage (vatamount) of the sum of Items Total plus the Handling Fee.

6.3.2 sqlMathExpression

The sqlMathExpression executes math operations on the SQL data stored in the tables in the SQL database. The sqlMathExpression method is implemented in the GRA Framework as a method that has the following two parameters:

- name of the table where SQL data is stored,
- SQL math expression.

The name of the table parameter enables execution of the SQL statements against any of available SQL tables.

The SQL math expression describes the math operations and SQL table columns involved. By changing the SQL math expression, it is possible to execute different math operations on different SQL table columns.

Access to the SQL data in the GRA Framework is based on the implementation of the Data Access Object pattern (Martin and Martin 2006). The GRA Framework implements a Data Object (DO) class and Data Access Object (GenericDAO) class. Each Data Object (DO) class employs an abstract (AbstractDO) class. The AbstractDO class contains processes that each class has to implement. The GenericDAO class contains methods that are responsible for reading, storing, and updating data from the SQL database. The GenericDAO method parameters are based on the AbstractDO type. The GenericDAO is able to process objects that employ the AbstractDO class.

The sqlMathExpression method in the GRA Framework is utilized as a method that requires two parameters: the data source parameter and the math expression parameter:

```
public string sqlMathExpression(string dataSource, string mathExpression)
```

The dataSource parameter requires the name of the table where SQL data is stored.

The mathExpression parameter describes the math operations and involved SQL table columns.

In the Retail Store application, the sqlMathExpression method is used for calculating the total amount of the selected items and that result is assigned to the itemstotal variable according to the math formula described in the Chapter 6.3.1 “MathFormula”:

itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100

6.3.3 addRowToDataSource

The addRowToDataSource method adds the data from one source SQL table row to another target SQL table row. The addRowToDataSource uses the GenericDAO and

AbstractDO to store and update data inside of the SQL database. The addRowToDataSource is designed as a method that requires one parameter, a target SQL table name:

- targetDataSourceName.

The targetDataSourceName is the name of the SQL table where a row should be stored is a part of the requirement description. The GPU uses the GenericDAO class to read a requirement description and generate source code where the targetDataSourceName parameter is replaced by the name of the target SQL table name stored in the requirement description.

The implementation of the GRA Framework in this dissertation requires that target SQL table has the same column names as the source SQL table. This is to simplify development. Otherwise, it would be necessary to create mapping of source SQL table columns to the target SQL table columns. Figure 8 shows the process of adding a row form source SQL table to the target SQL table:

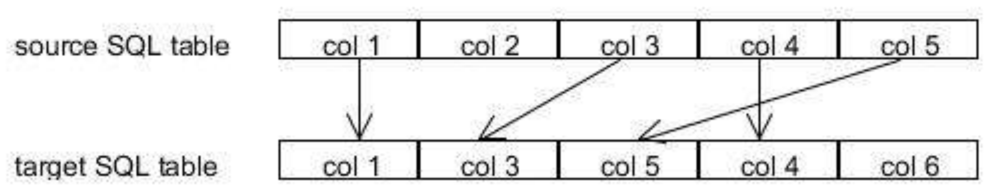


Figure 8 addRowToDataSource

In Figure 8, all columns with the same name will be added to the target SQL table. The “col 2” value will not be added to the target SQL table because the target SQL table does not have “col 2”; “col 6” in the target SQL table will be empty or null as well, depending on the specific implementation platform and “col 2” data type.

The addRowToDataSource method, in combination with the updateRowToDataSource method described in Chapter 6.3.4 “updateRowToDataSource”, can satisfy a wide spectrum of related programming issues, enable inserting and updating SQL tables’ row dynamically, and create new relations and complex tables from the already existing database tables.

6.3.4 updateRowToDataSource

The updateRowToDataSource utilizes the GenericDAO and AbstractDO to store and update data inside of the SQL database. The updateRowToDataSource is designed as a method that requires one parameter, a target SQL table name:

- targetDataSourceName.

While the addRowToDataSource method inserts a new row in the SQL table, the updateRowToDataSource updates an existing SQL table row. The updateRowToDataSource method requires that the target SQL table has the same column names as the source SQL table/tables. Figure 9 shows an example of updating the existing target SQL table row:

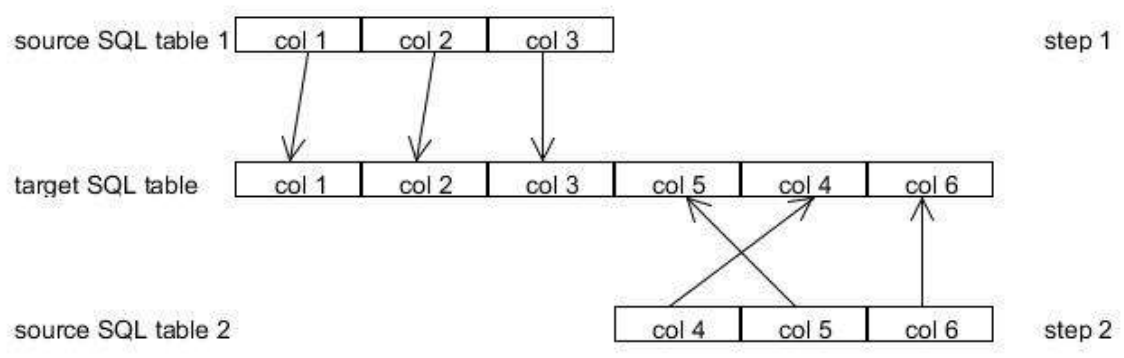


Figure 9 updateRowToDataSource

In Figure 9, the target SQL table rows are updated from two different source SQL tables in two different steps. In each step the corresponding columns are updated. The number of updating steps is not limited, but a single parameter in the updateRowToDataSource method enables only one update operation per step.

6.4 Demonstrate Working Software during the Requirement Negotiations Process

Generating source code for each particular object would not be sufficient to demonstrate the software application. Before it is possible to demonstrate a working application, the source code needs to be compiled and linked. These tasks can be automated with scripting languages, such as UNIX shell script, Windows Power Schell, or the Python languages. Another solution is to use Web-related technologies, like JavaScript or ASP.NET, and employ the Web browsers as a run-time environment.

In this dissertation are provided advantages that can offer programmers Microsoft ASP.NET technology and a Microsoft Visual Studio development environment. The Microsoft Visual Studio development environment compiles each class to an object code when it is necessary and enables Web page access to the object's properties and event handlers. Therefore, it is not necessary to compile and build generated source code before execution.

6.5 Provide a collaborative environment

A collaborative environment in the Internet era requires data- and information-sharing between stakeholders anytime and anywhere. This is important in the distributed development environment when software is created by multiple distributed development teams that can be located in different countries, on different continents, and in different time zones.

Data- and information-sharing is not always sufficient and the collaborative environment needs to be able to provide data and information history and automatic notification in the event of any kind of data or information changes.

The history of changes can be managed by versioning or by a design that prevents modification and deletion of the existing data and information, and supports only adding changes.

The automatic notification can be implemented as an automatic mail notification to stakeholders. "Automatic mail notifications are a powerful tool for information-sharing and distribution, and can save a lot of time spent on writing and answering e-mails, and significantly reduce communication overhead. Besides informing stakeholders that a requirement has been changed, a mailed message contains all the details about the change. While creating such a message is an easy job for a computer, for a human being this can be a daunting and error-prone task that can take a lot of time, remove focus, and affect creativity, effectiveness, and productivity" (Bulajic et al. 2013).

7 GRA Framework Validation

The GRA Framework is used for the development of a fictive application called Retail Store. The more detailed Retail Store application example is presented in Chapter 15 "Appendix C – Retail Store Example". The Retail Store application is available at the http://www.port85.com URL for testing purposes. The test documentation is available in Chapter 16 "Appendix D – Retail Store Test Documentation".

The Retail Store application is designed for E-commerce and is implemented as a Web application for the online sale of merchandise. The Retail Store application requirements are described by fictive User Stories. The RetailStoreProject User Story describes the application's high-level requirements, and the SalesDepartmentStory and BuyerStory User Stories provide more detailed requirements information.

The RetailStoreProject User Story:

"As the Retail Store, we want to sell our products on-line through the Internet in order to increase product availability, get in touch with more customers, and increase sales and profit".

The SalesDepartmentStory User Story:

"*As a Salesman, I need to be able to add a product to the product list for sale, update and remove products from the product list in order to enable product on-line sales, and keep information such as product descriptions, prices, and quantities up-to-date*".

The BuyerStory User Story:

"As a Buyer I need to be able to:

** select a product,*

** enter the desired product quantity*

** add products to a shopping cart*

** review and update a shopping list*

** create an order*

** provide a delivery address*

** purchase a product using a credit card*

in order to save time and resources used during the purchasing process".

Each User Story can be described in more detail with Use Cases and Test Cases, but it would draw attention away from the GRA method. The purpose of the Retail Store example is to demonstrate how this method collects requirements and create executables for requirement demonstration.

7.1 Retail Store Example Application

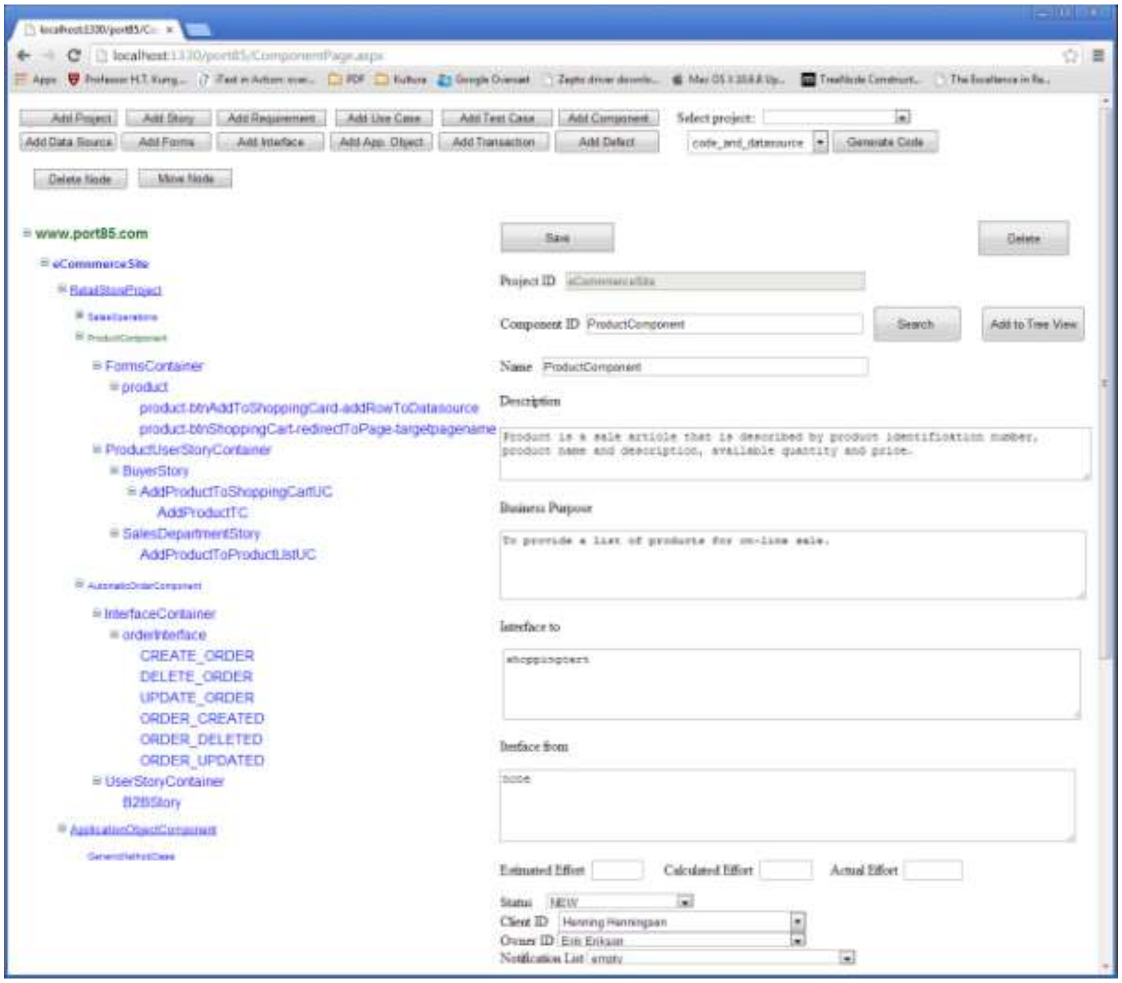
From the RetailStoreProject User Story, the following can be identified:

- ProductComponent object,
- Sales Operation.

Although a Product from a design point of view can be considered a single object, in the case of the GRA Framework, it is designed as a collection of objects. Using the name "ProductComponent" makes clear that the product is a collection of objects. Besides data components and methods, User Stories, Use Cases, and Test Cases can be assigned to the ProductComponent, creating a Form that will visualize a Product and enable the execution of interactive methods. The number of objects that can be assigned to the Product Component is not limited; any number of Test Cases can be designed, for example.

How the Product will be represented is a designer choice and this is only an example. The Product can be represented by a User Story object, for example, and Use Cases, Test Cases, and Forms can be attached to the User Story.

The ProductComponent is defined as "a sales article that is described by a product identification number, product name and description, available quantity, and price" and is used "to provide a list of products for on-line sales". Figure 10 shows all ProductComponent objects:


www.port85.com
eCommerceSite
RetailStoreProject
SalesOperations
ProductComponent
FormsContainer
product
product.btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomaticOrderComponent
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
GenericMethodCase

Select project:
code_and_datasource

Project ID: eCommerceSite
Component ID: ProductComponent
Name: ProductComponent
Description: Product is a sale article that is described by product identification number, product name and description, available quantity and price.
Business Purpose: To provide a list of products for on-line sale.
Interface to: shoppingcart
Interface from: none
Estimated Effort:
Calculated Effort:
Actual Effort:
Status: NEW
Client ID: Henning Henningsen
Owner ID: Erik Eriksen
Notification List: empty

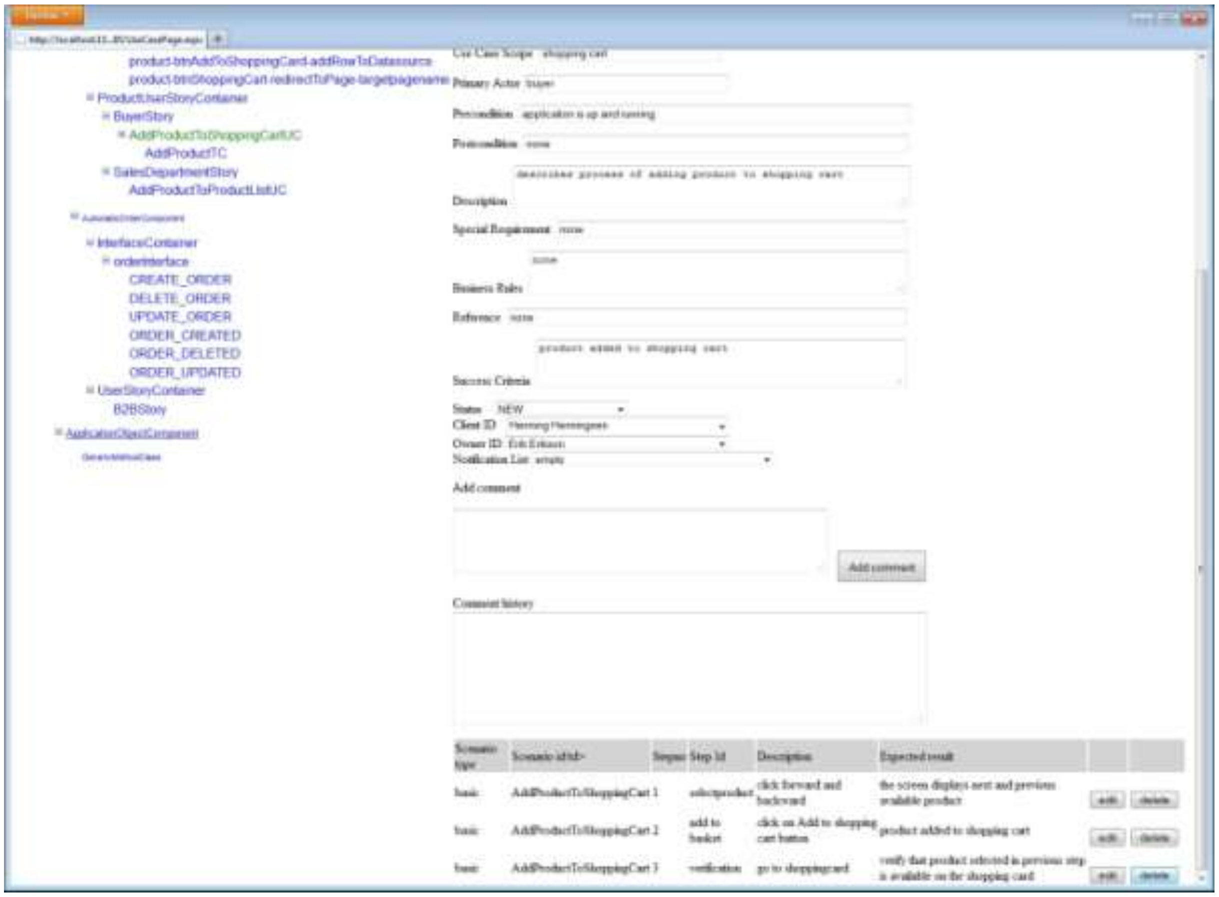
Figure 10 Product Components

The left part of the screen contains a tree view structure and each node corresponds to the GRA Framework object, such as Project, User Story, Use Case, Test Case, and Form for example. The right side of the screen contains the form that describes the corresponding GRA Framework object structure.

The ProductComponent contains:

- FormsContainer,
- UserStoryContainer.

These two containers are used for storing Form design information and the User Story, SalesDepartmentStory, and AddProductToShoppingCartUC Use Case. Within the SalesDepartmentStory, the Sales Department and Salesman expectations are described. The SalesDepartmentStory User Story is described in more detail by the AddProductToProductListUC Use Case. The Use Case is a child node of the User Story, but the Use Case can be moved to its own container, and a link can be assigned to each Use Case that points to a corresponding User Story or Component or any other Object. In this Framework version, links are provided to the parent node and descriptions. Figure 11 illustrates a Use Case template and guidelines, and revealing more details about a Product object:


product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
[illegible]
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
[illegible]

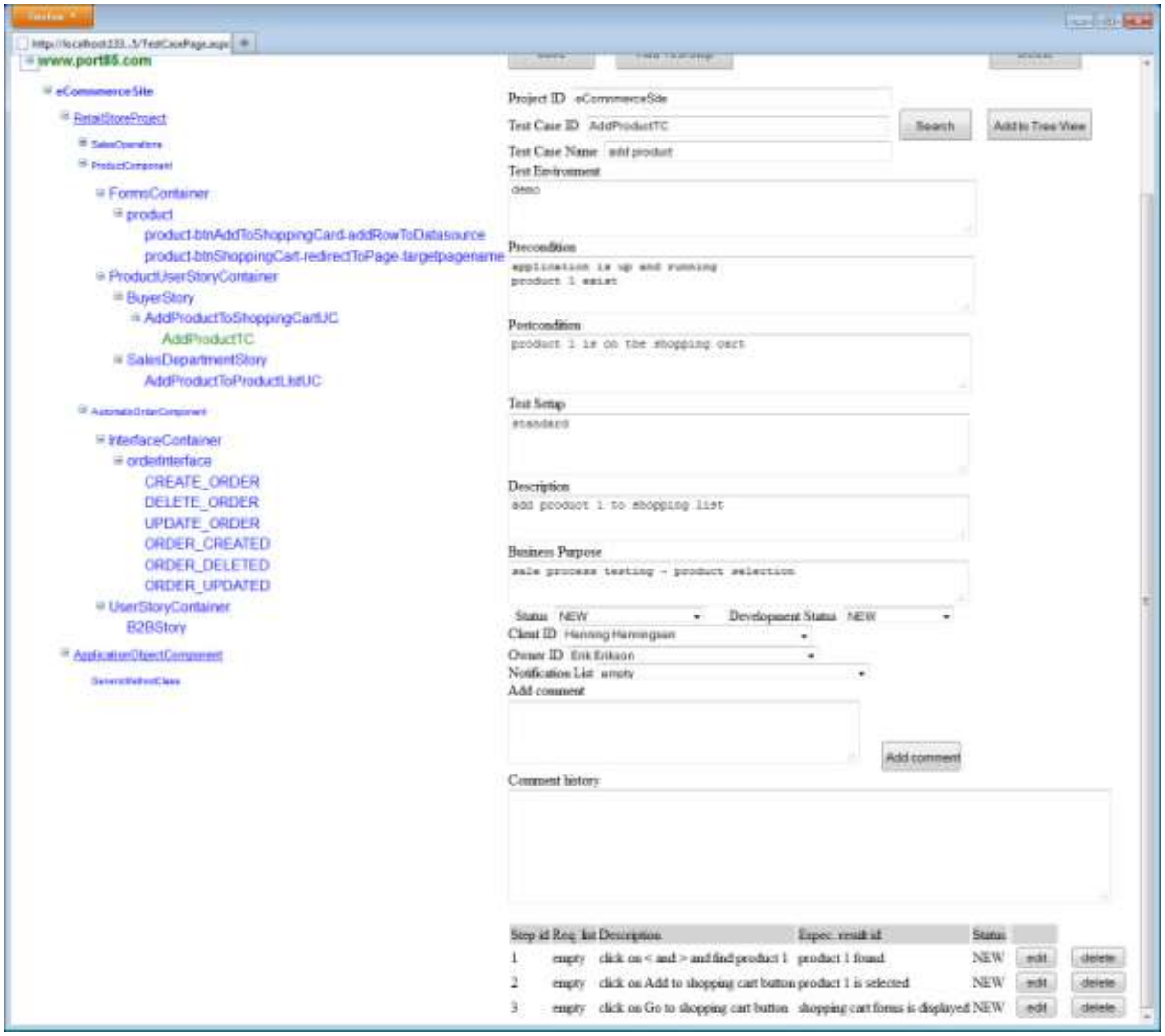
Use Case Scope: shopping cart
Primary Actor: buyer
Precondition: application is up and running
Postcondition: none
Description: describes process of adding product to shopping cart
Special Requirement: none
Business Rules: none
Reference: none
Success Criteria: product added to shopping cart
Status: NEW
Client ID: Henning Henningsen
Owner ID: Erik Eriksen
Notification List: empty
Add comment
Comment history

Scenario type	Scenario id\<td\>	Stepno	Step Id	Description	Expected result		
basic	AddProductToShoppingCart	1	selectproduct	click forward and backward	the screen displays next and previous available product	edit	delete
basic	AddProductToShoppingCart	2	add to basket	click on Add to shopping cart button	product added to shopping cart	edit	delete
basic	AddProductToShoppingCart	3	verification	go to shoppingcard	verify that product selected in previous step is available on the shopping card	edit	delete

Figure 11 AddProductToShoppingCartUC Use Case

The AddProductToShoppingCartUC Use Case describes all the steps and the order of execution to add a product to the shopping list. The Use Case object is a template and a guideline for creating the Use Case. The Framework enables a designer to add a new step, or update or delete any existing step features.

The purpose of the AddProductToShoppingCartUC Use Case is for clarifying the requirements described in the parent node, the BuyerStory. Figure 12 illustrates the Test Case template and guidelines:



Project ID eCommerceSite
Test Case ID AddProductTC
Test Case Name add product
Test Environment
demo
Precondition
application is up and running
product 1 exist
Postcondition
product 1 is on the shopping cart
Test Setup
standard
Description
add product 1 to shopping list
Business Purpose
sale process testing - product selection
Status NEW Development Status NEW
Client ID Henning Henningsen
Owner ID Erik Erikson
Notification List empty
Add comment
Comment history

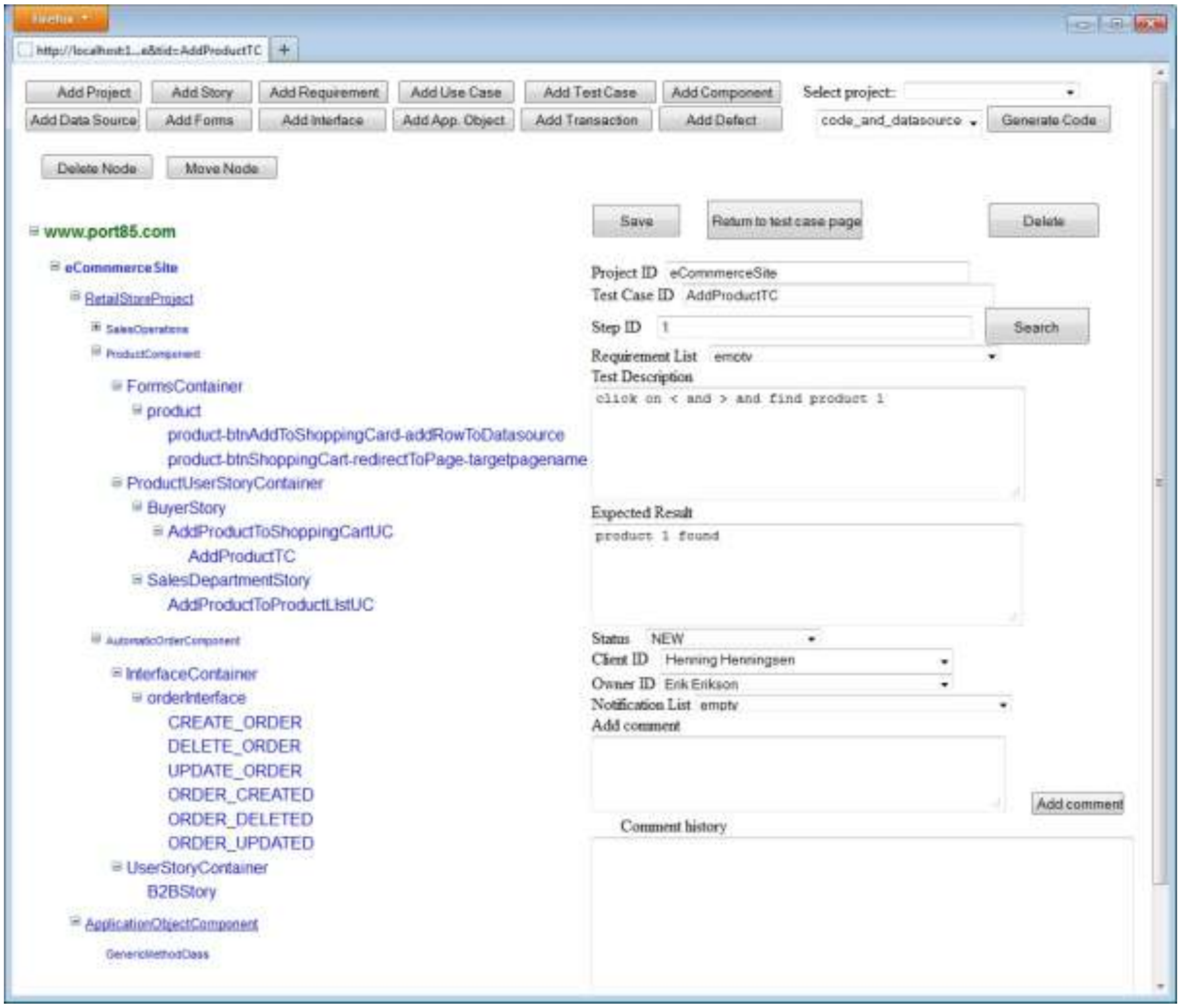
Step id	Req. list	Description	Expec. result id	Status		
1	empty	click on < and > and find product 1	product 1 found	NEW	edit	delete
2	empty	click on Add to shopping cart button	product 1 is selected	NEW	edit	delete
3	empty	click on Go to shopping cart button	shopping cart forms is displayed	NEW	edit	delete

Figure 12 AddProductTC Test Case

The Test Case template and guidelines provide information about Test Case's purpose as well as describing details about each Test Case step.

The objects of the Test Case and Test Case steps provide a standard set of database operations, such as insert, update, delete, and search. It is possible to copy a Test Case or Test Step by changing the ID and using the Save option. This is generally an available feature for all Framework objects.

Figure 13 illustrates the Test Case template and guidelines:



```
www.port85.com
  eCommmerceSite
    RetailStoreProject
      SalesOperations
      ProductComponent
        FormsContainer
          product
            product-btnAddToShoppingCard-addRowToDatasource
            product-btnShoppingCart-redirectToPage-targetpagename
        ProductUserStoryContainer
          BuyerStory
            AddProductToShoppingCartUC
              AddProductTC
          SalesDepartmentStory
            AddProductToProductListUC
      AutomaticOrderComponent
        InterfaceContainer
          orderInterface
            CREATE_ORDER
            DELETE_ORDER
            UPDATE_ORDER
            ORDER_CREATED
            ORDER_DELETED
            ORDER_UPDATED
        UserStoryContainer
          B2BStory
    ApplicationObjectComponent
      GenericMethodClass
```

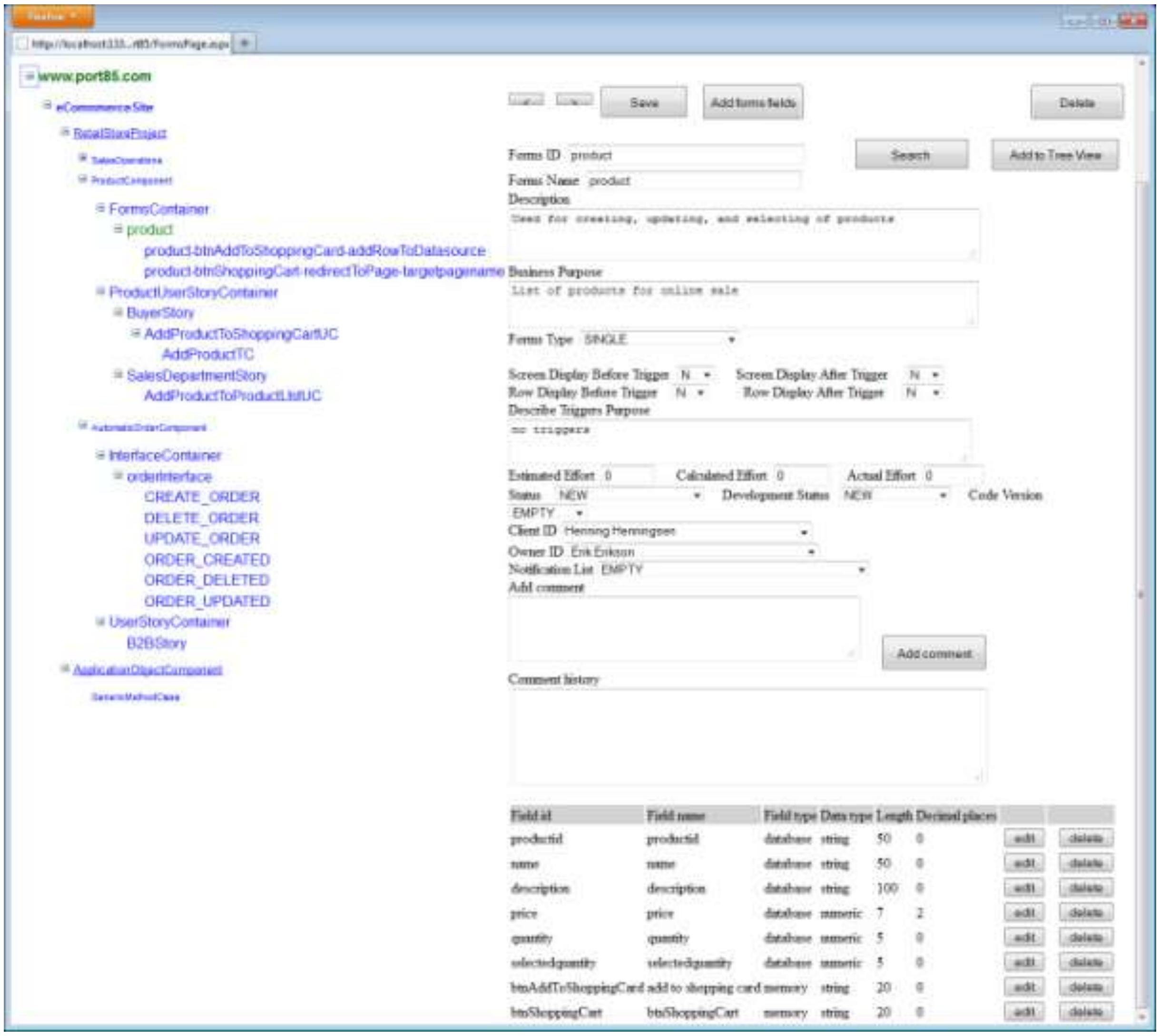
Select project:
code_and_datasource

Project ID eCommmerceSite
Test Case ID AddProductTC
Step ID 1
Requirement List empty
Test Description
`click on < and > and find product 1`
Expected Result
`product 1 found`
Status NEW
Client ID Henning Henningsen
Owner ID Erik Erikson
Notification List empty
Add comment
Comment history

Figure 13 AddProductTC Test Step

The GRA Framework enables the adding, moving, and/or deleting of each object or node. Deletion of a node will not delete the node's description. The node description will still exist and can be reused by another node. This is the implementation's specific feature.

The ProductComponent contains the FormsContainer node. While the previously mentioned objects are used for design and documenting purposes, the Forms object is used by a Code Generator to generate source code and executables. Figure 14 illustrates the Forms objects template and guidelines:


www.port85.com
eCommerceSite
RetailStoreProject
SalesOperations
ProductComponent
FormsContainer
product
product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomaticOrderComponent
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
GenericMethodClass

Forms ID: product
Forms Name: product
Description: Used for creating, updating, and selecting of products
Business Purpose: List of products for online sale
Forms Type: SINGLE
Screen Display Before Trigger: N
Screen Display After Trigger: N
Row Display Before Trigger: N
Row Display After Trigger: N
Describe Triggers Purpose: no triggers
Estimated Effort: 0
Calculated Effort: 0
Actual Effort: 0
Status: NEW
Development Status: NEW
Code Version: EMPTY
Client ID: Henning Henningsen
Owner ID: Erik Eriksson
Notification List: EMPTY
Add comment
Comment history

Field id	Field name	Field type	Data type	Length	Decimal places		
productid	productid	database	string	50	0	edit	delete
name	name	database	string	50	0	edit	delete
description	description	database	string	100	0	edit	delete
price	price	database	numeric	7	2	edit	delete
quantity	quantity	database	numeric	5	0	edit	delete
selectedquantity	selectedquantity	database	numeric	5	0	edit	delete
btnAddToShoppingCard	add to shopping card	memory	string	20	0	edit	delete
btnShoppingCart	btnShoppingCart	memory	string	20	0	edit	delete

Figure 14 ProductForms Forms

The details about using the ProductForms form’s data for generating source code are explained in Figure 5 in Chapter 6.2 “Generate Source Code without Manual Programming”.

It is possible to assign an action to each of the Form’s fields. The action can be a validation of the field type, an execution of a piece of code, an algorithm, a call to internal and external procedures, a redirection of the application flow, an execution of a request for the form’s data processing, or any other kind of action that can be executed by source code. The Application Objects are responsible for creating actions. The Application Objects belong to the GRA Framework objects responsible for storing data in structured text format that are used to generate source code, and the Application Objects are responsible for backend or batch job processing. Each of the Application Objects is represented by a corresponding class and class methods.

The Code Generator is responsible for adding code to each form's fields and the code is executed when an event on that field is fired. This is a straightforward process and is guided by the Application Object. If the Code Generator needs to add code to the form's field, then the Application Object class and method code should already exist. In the Retail Store application, the GenericMethodClass Application Object is used, and the GenericMethodClass methods include:

- addRowToDatasource – adds current objects data to the output data source,
- mathFormula – is used for math operations,
- redirectToPage – used for moving workflow to the next Web page,
- sqlMathExpression – used in case when calculations are executed by using SQL statement and data stored in the database table,
- updateRowToDatasource – used for update row in the database by using current object data.

7.2 Generating Source Code and Executables

Generated source code and executables are used for requirement validation, and any further work is directly dependent on the validation's results. The forms are used for requirement visualization, test, and validation of future product features. The generated source code and executables are used for validating whether there is a sufficient level of details.

For example, the mathFormula assigned to the orderdemo forms total field is described as "*itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100*"

If any of the operands are missing, a compiler will issue an error.

If any operand contains an illegal value, such as a null value, the compiler will issue an error.

If there are no compiler errors, the executables will enable the testing of the math formula. The user will be able to assign different values to each or a selected number of operands, and then inspect the displayed calculation results.

To enable validation, it is necessary to generate source code and executables. This job is accomplished by the Code Generator. For each Framework object, the Code Generator reads, the design information stored in the database and translates them to the C# source code. It will be necessary to choose the desired design object and generator options, and then involve the Code Generator with a single click on the Generate Code button.

Figure 15 illustrates this button's position and options:

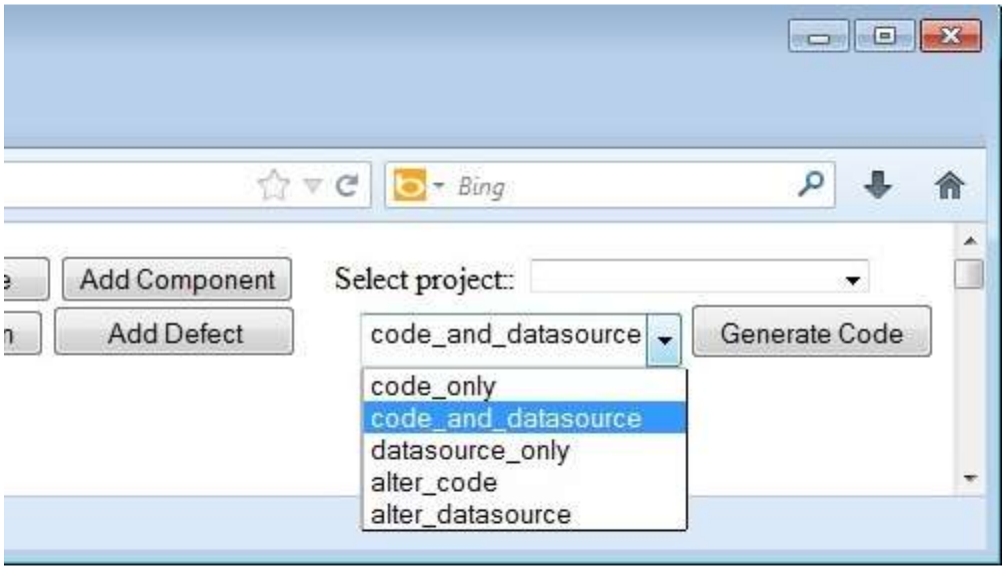


Figure 15 Generate Code

In the dropdown list are the available options for creating code_only, code_and_datasource, datasource_only, or for otherwise altering code and data source.

Once the Forms are selected and generated, the Framework should redirect the workflow to the last generated page. Figure 16 illustrates the Generate Code result:

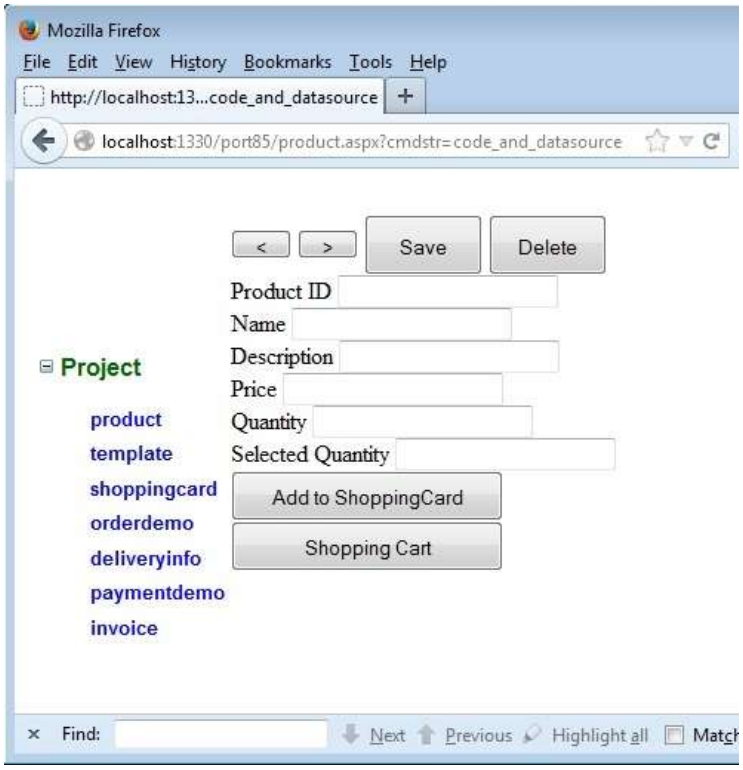


Figure 16 Product Forms Generated

On the left side of the screen is the navigation tree that shows all generated objects. On the right is the last generated form.

The GRA Framework's job is accomplished when the source code and executables are generated. The GRA Framework provides a working application and requirement demonstration. The team responsible for the requirement negotiation can use the generated application for requirement testing and tuning.

Generated forms are fully functional applications. On the top of the product forms are previous ("<") and next (">") navigation buttons, as well as "Save" and "Delete" buttons. Attached to the "Save" button are insert and update SQL row functions. If an SQL row already exists, it will be updated; otherwise, a new row will be inserted. Assigned to the "Add to ShoppingCart" is a generic method addRowToDatasource and to the "Shopping Cart" button is assigned a redirectToPage method. The "redirectToPage" method assigned to the "Shopping Cart" button is a generic system that can be used to test application workflow.

8 Summary of GRA Features and Comparison to other Approaches

The solution presented in this dissertation is generally applicable for business and E-Commerce applications that are based on the user's input where storing and retrieving data can be described by programming language and SQL available data types.

The GRA Framework does not require manually writing source code. The code is already written and is a part of the GRA Framework's templates and libraries.

The requirement description is guided by the GRA Framework objects and object attributes, and these guidelines ensure a sufficient details level for each requirement description. The sufficient level of details is represented by the Framework's predefined set of objects and object attributes. These attributes are guidelines for specifying a sufficient numbers of details.

The GRA Framework object functionality supports the negotiation process and demonstrates a solution. This demonstration is different from prototyping because it does not require establishing a development environment or development team, nor does it require the writing of code. The demonstration is created on demand, and is a part of the Framework.

While it can be argued that prototyping is already an established practice, the GRA is significantly different.

While a prototype is developed in a separate development process by programmers, the GRA generates a working application during requirement negotiation process together with the customers.

While a prototype is developed by writing source code in the computer specific programming language, the GRA generates source code from a requirement description described by the customer's language.

While the prototype development can take weeks or months, the GRA generated source code and executables can be available immediately during the requirement negotiation.

Requirement demonstration is based on the data provided by requirement negotiation parties. Each demonstration is documented by the participants of the negotiation process, and executables are product of the requirements as described by customer language.

Using customer language is an important motivation for the customer's active involvement. A customer can follow the process, make decisions, and test those decisions.

Although the customer's active involvement is important for the project's success, it is an unrealistic expectation that the customer will be available the entire time of the process. The customer has his or her own job and responsibilities. A customer's motivation and interest are best at the beginning of a project. The interest seen during the first releases decreases with every next release, and the amount of lost motivation is proportional to the number of defects found and the customer's specific amount of necessary work on the project. A customer's interest is refreshed when the project is closer to deadline in expectation of the final release.

To be able to participate actively, a customer should understand the process and language. This is a reason why the Framework uses the customer's language, not scripts or technical notations.

A predefined set of generic objects is included in the Framework to eliminate the need for writing code during the requirement negotiation process. When the requirement negotiation process starts, any break or interruption can affect the process, decreasing motivation or splitting negotiations in different directions. Sometimes a lunch break can be enough to cause distractions. What might happen if negotiations need to wait weeks or a month before release?

The experience collected during the Framework's development shows that creating new generic objects speeds up if there are more generic objects available. The reason for this is that generic objects programming increases object reusability and promotes the design of the reusable classes and methods. The new generic object reuses existing features, classes, and methods.

8.1 Software Development Method Generalized Requirement Approach (GRA) vs. Agile/Prototyping

Although it can be argued that the GRA is an agile and fast prototyping approach, the GRA differs from both.

The first difference is that the proposed solution does not require specific development and environment setup. The method’s implementation by default has a development and test environment.

While agile/prototyping needs to write a source code and create a release, the GRA is based on a set of predefined artifacts that create executables by default. Therefore, in GRA, code writing is not necessary. The GRA’s focus is on the requirement testing, and providing sufficient details as required by each of the GRA’s artifacts.

While an agile/prototyping development team creates a first release, in the GRA Framework, a customer is supposed to be the driving force in creating an initial version and defining the artifacts’ details.

In the agile/prototyping method, development starts when only a part of a requirement is known, and it is assumed the requirement be well known. The GRA system assumes that the requirement is not well known until it is validated. While agile validates the requirement at the end of development iteration, GRA validates requirement during the requirement negotiation process.

While agile/prototyping writes source code manually, the GRA uses a set of predefined artifacts to generate source code and validate requirements.

8.2 Software Development Method Generalized Requirement Approach (GRA) vs. Visual Modeling

While visual modeling is based on the diagrams and relations between the diagrams that are then translated to executable code, the current method is based on a data-driven development method, and the executable code is generated from the requirement-structured text descriptions.

Visual modeling uses a complex notation, but the GRA uses the customer’s language. The customer decides what terminology will be used.

In the case of visual modeling, “Visualize Design” is one of the first steps in the software development process, after requirement elicitation. With the GRA approach, requirement elicitation is an iterative process that involves a requirement description and requirement validation cycles.

8.3 Software Development Method Generalized Requirement Approach (GRA) vs. Formal System Development Methodology

A formal specification is usually written in a concrete language that has a precisely defined syntax and semantics (Wing 1988). A formal specification is executed by a machine-executable interpreter, like Prolog or Lisp.

Formal System Development methodology is based on the systematical formal mathematical transformations of requirements into more detailed mathematical representations that are finally converted into an executable program.

The GRA is not based on systematical formal mathematical transformations, nor is language specific, although it can and does generate a language-specific source code. The GRA is not described by mathematic formulas, but rather by descriptions that are expressed in the customer's language.

The GRA stores descriptions in the requirement repository that consist of the database tables and relations. The GRA generates source code from information stored in the structured text format. Generated source code can be used for further development, for modifying existing features, and for adding new features.

8.4 Software Development Method Generalized Requirement Approach (GRA) vs. Rapid Prototyping

Although there are many similarities between rapid prototyping and the GRA, there are also many important differences.

The GRA does not require manual code writing. The rapid prototype is usually created using the drag-and-drop of the controls to the forms, setting control properties and events, and manual writing source code. This is not a part of the GRA. The GRA works with the already predefined components and controls, and does not write a source code manually. While rapid prototyping uses computer language-specific code for creating executables, the GRA uses customer language and structured text descriptions.

While in the case of rapid prototyping the developers, programmers, designers, and IT professionals are all involved in creating an executable application and writing code, using the GRA, executables are created in the background and the person who creates the executables does not need to be aware of how it is done, or what kind of software was used.

The rapid prototyping's driving force is an IT professional who is an expert for a particular software. When using the GRA, the driving force is the customer and requirement negotiation team.

While in rapid prototyping the technical knowledge is dominant and important, in the GRA, business knowledge is equally important. The GRA's focus is the description of business needs, and business components and entities.

9 Generalized Requirement Approach Limitations

The GRA's limitations are related to non-functional requirements, such as performances, security, robustness, and further design development. The GRA is not suited for non-functional requirements. While generating source code can be a good starting point for further application software development, the source code generated by the Framework is not optimized. Data normalization, code optimization, and security, according to this method, are moved to the next step and in this step developer specialists and experts will need to be involved for these kinds of tasks.

The same is valid for the database design. The data model is not normalized and using a not-normalized data model is preferable because it simplifies the generic methods writing. The GRA-created data model cannot be used in the production environment and will need normalization, indexes, and performance tuning.

Although the generic methods are written to support the generation of broad features, it is not possible to know in advance what specific feature is going to be requested by customers.

The proposed solution is not recommended to applications that are based on complex data models and relations, simulations, graphical applications, technical applications, and complex algorithms.

The implementation of the proposed model is not a simple task and requires experienced developer knowledge. Generic methods are more difficult to debug. The use of abstract classes and interfaces can make the code obscure and hide implementations. The size of the Framework in this implementation is more than 50,000 lines of code.

Any changes in the Framework's engine can affect a large part of the Framework.

Writing generic code is different than the standard programming approach. It requires time to adapt in order to a create solution using the same clump of code.

Designing new features can take more time than was required in the classic procedural or object-oriented programming approach.

The fast code generation can hide a problem's complexity give the customer the wrong idea that a solution can be created quickly.

10 Research Contribution

"If you develop software without understanding the requirements, you're wasting your time. On the other hand, if a project spends too much time trying to understand the requirements, it will end up late and/or over-budget. And products that are created by such projects can be just as unsuccessful as those that fail to meet the basic requirements." (Alan Mark Davis, "Just Enough Requirements")

Requirement management is one of the most important parts of the software development process. Requirement management is starting point for any further work. Without a requirement, it is meaningless to create the architecture and design or write any line of code. The proposed solution, the Generalized Requirement Approach (GRA), can contribute to:

- Closing the gap between requirement specification and requirement validation,

- Producing an environment where the requirements definition is guided by an already predefined set of artifacts and artifact attributes, and where requirements can be executed, analyzed, observed, and validated,
- Providing a solution for the Known Requirements Syndrome, the IKIWISI ("I'll know it when I see it") Syndrome, the Yes, But syndrome ("That is not exactly what I mean"), and the Undiscovered Ruins Syndrome ("Now that I see it, I have another requirement to add"),
- Providing an environment where all requirement negotiation-related documentation is located in one place, and is up-to-date by default,
- Promoting the customer's active participation, and increasing the customer's motivation for project success,
- Effectively using the customer's and IT developer's time, and reducing communication overhead by providing a sufficient level of details during the requirement negotiation process,
- Reducing or removing misunderstanding between clients and IT developers.

Although not a primary purpose of this research, this method might also be used for improving project estimations, resource allocation, and impact analysis.

11 Conclusion

This dissertation discusses business software development efficiency and proposes a different method that improves development effectiveness. This dissertation offers a solution to the following requirement negotiation issues:

- the IKIWISI Syndrome ("I'll know it when I see it"),
- the Yes, But Syndrome ("That is not exactly what I mean"),
- the Undiscovered Ruins Syndrome ("Now that I see it, I have another requirement to add"),
- the insufficient details level specification.

In this dissertation the following has been accomplished:

- discussed existing software development methodologies analysis,
- described the new method for business application development,
- developed the Framework, a tool for business application development,
- demonstrated the Framework implementation to the business application development,

- demonstrated solution feasibility to the business application development and presented advantages compared to other software development methods.

Besides discussing research associated to the related works and the theoretical part that describes the proposed solution, the GRA Framework has been implemented as a part of this dissertation and a demonstration application example was developed. The application example demonstrates the proposed solution and addresses the above-mentioned requirement negotiation issues.

The result of the experiment, in the form of the Retail Store application, demonstrates the proposed solution's feasibility. The predefined set of the Framework's objects and code that uses data defined during requirement negotiation process is sufficient for generating a working application without a need for writing code manually. The Framework's object attributes are guidelines for specifying a requirement and providing the sufficient level of details. The data stored in the predefined set of objects are described by customer language. The generic programming units, as part of the GRA Framework, are able to generate a working application example from the requirement specification data stored in the GRA objects. The generic programming units—the GRA Framework's objects where generic code is stored—are able to generate:

- Source code (front-end and back-end processing codes),
- HTML pages,
- Code-behind pages,
- Object-relational data mapping,
- CRUD set of permanent storage operation,
- Navigation and menus controls.

Application code generated in this Framework implementation is Microsoft .NET specific, because the GRA implementation was adapted to Microsoft Visual Studio IDE and .NET requirements, but the design can be reused by other technology that supports event-driven and interactive communication between the end-user and the software executable code, such as, for example, Java or JavaScript.

The generated executables are fully functional applications that can be executed and tested according to the requirement description. The Retail Store demo application demonstrates workflow and algorithms, and can be used for ad-hoc testing.

The results are demonstrated through the development of a purpose that is typical for E-Commerce business applications. The GRA feasibility is validated through the development of a framework that is able to create executables from the GRA data collected by the GRA guidelines during requirement negotiation process, and stored in the common repository.

The reader can test the proposed method and the GRA Framework by using this dissertation's results and test documentation described in Chapter 16, "Appendix 16 – Retail Store Test Documentation".

This dissertation proposes a new approach to the requirement negotiations process by:

- Creating a working application example without manual programming,
- Creating a working application example together with a customer during the requirement negotiation process,
- Creating a generalized approach to a wide spectrum of common programming issues.

While it can be argued that prototyping is already established, the GRA is significantly different. The GRA approach does not require development environment setup, resource allocation, or manual code writing.

While a prototype is developed in a separate development process by programmers, the GRA generates a working application during the requirement negotiation process together with the customers.

While a prototype is developed by writing source code in a computer-specific programming language, the GRA generates source code from specifications described in the customer language.

While waiting for a prototype can take weeks or months, the GRA's working application example is generated immediately.

While prototyping implements specific requirements for particular business issues, the GRA is a generalized approach to a wide spectrum of the common programming issues related to the creation of the business software application.

Comparing prototyping and the proposed solution is not always appropriate. Prototyping can be used for purposes other than requirement clarification. For example, structural prototypes or proof-of-concept prototypes work through layers and is used to demonstrate feasibility of architecture and design.

The primary purpose of the solution proposed in this dissertation is requirement clarification. The experiment with the Retail Store application is sufficient to establish proof of concept, but it is not sufficient to make any conclusion about the solution's potential. This means that any expectation related to this product future is a subjective opinion and as such is the subject of criticism.

What can be concluded is that the implemented example can be used as a proof of concept. According to the up-to-date collected experience of the author, the critical part of this approach is providing a sufficient amount of the features that are in the GRA represented by an Application Object. The Application Object represents the classes and generic methods that solve any particular programming issue. For example, it can test a unique ID, moving rows from one relation table to another, or creating new entities that are combinations of existing entities. In the Retail Store demo application, an illustration of such features is provided by the methods stored in the GenericMethodClass. For example, the addRowToDataSource generic method is able to add a current data source row to any other data source that is specified in the method's parameters.

From the requirement clarification point of view, the proposed solution provides an advantage because the working software application can be generated immediately.

Diagrams and overviews can hide misunderstandings, as well as other details that can later cause significant delays. The issues and misunderstandings are discovered during implementation, when low-level details are required and ambiguities become visible.

The proposed method enables documenting requirements using User Stories and Requirements, and the description of low-level details by Forms, Data Sources, Algorithms, and Interfaces. Defining low-level objects and low-level object attributes has the following purposes:

- Admonish requirement negotiations participants to describe a sufficient level of details,
- Provide executable code generation during the requirement negotiation process.

From the low-level detail descriptions, an application is generated that can be used for demonstration and testing purposes. The generated application does not require installation and deployment. The generated application is a Web application and can be shared with requirement negotiation participants anywhere where an Internet connection is available. The proposed solution can save a lot of time and resources used for code writing, installation, and deployment.

Despite that the implementation of the GRA Framework is sufficient for demonstrating the method's use in generating source code and executables, this is not yet a software product; this implementation is limited to academic and research purposes. The proposed solution needs to be implemented as a software product. The solution needs to be evaluated on a full-scale level of industrial projects. The solution needs to reach a certain level of maturity to be evaluated properly. This requires further investment.

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13 Appendix A – Definition of Terms

In this document standard definitions of terms are used according to the “IEEE Standard Glossary of Software Engineering Terminology”, IEEE-Std 610.12 (“IEEE Standard Glossary of Software Engineering Terminology” 1990) as well as the Microsoft .NET technology (“Visual Studio and .NET Framework Glossary” 2013).

Only terms where definition differs from IEEE-Std 610.12 standard and Microsoft .NET standard are described in this chapter, Chapter 13 “Appendix A – Definition of Terms”.

13.1 Generic Programming Unit

The Generic Programming Unit (GPU) is a code, method, class, or module that generates source code from the requirement description stored in the GRA Framework Artifacts and the GRA Framework Templates and Libraries. The GPU is part of the GRA Framework.

13.2 Generalized Requirement Approach

This is a software development method based on requirement validation during the requirement negotiation process. Requirement validation is accomplished by automatic generation of the source code and executables from the requirement description, described using the customer’s language and stored in the structured text format.

13.3 Generalized Requirement Approach Framework

The GRA Framework (GRAF) is the implementation of the Generalized Requirement Approach (GRA) method. The GRA Framework is responsible for guiding a user to specify requirements, store requirement descriptions in the structured text format, and generate source code and executables that are used for requirement validation. The GRA Framework contains the GRA Framework Templates and Libraries, and the Generic Programming Units.

13.4 GRA Framework Artifacts

The Generalized Requirement Approach Artifacts are objects that are responsible for documenting requirements, storing requirement descriptions in the structured text format, guiding the user to specify a sufficient level of detail for translating requirements to a computer specific language, and generating source code.

13.5 Generalized Requirement Approach Framework Templates and Libraries

The GRA Framework Templates and Libraries contain the templates and methods that are used for generating source code specific to the implementation technology. For example, if the implementation technology is Microsoft ASP.NET, the GRA Framework needs to use templates and libraries adapted to generate source code according to the syntax of the ASP.NET languages, such as C# or VB.NET. If the implementation technology is Java or Java Server Pages (JSP), then the GRA Framework will use templates and libraries that are adapted to generate source code according to Java and JSP syntax.

14 Appendix B – Generating Source Code

The process of generating source code is illustrated in the “generating source code for PRODUCT form” example. The example is generated according to the Microsoft ASP.NET specific implementation requirements and for this example uses Microsoft ASP.NET specific templates and libraries. Figure 5 illustrates the process of generating source code. Table 1 describes the PRODUCT form structure:

form name	field name	data type	length	Dec. Places	control type	action type
product	productid	string	50	0	TextBox	N
product	name	string	50	0	TextBox	N
product	description	string	100	0	TextBox	N
product	price	numeric	7	2	TextBox	N
product	quantity	numeric	5	0	TextBox	N
product	selectedquantity	numeric	5	0	TextBox	N
product	btnAddToSC	string	20	0	Button	addRowTo(ShoppingCart)
product	btnShoppingCart	string	20	0	Button	redirectTo(ShoppingCart)

Table 1 Product Form Fields Description

The FORM description is stored in the Database table. The Actor requires generation of the PRODUCT form. The GPU reads all product fields and generates code.

The generation of source code is performed according to the illustration in Figure 4. The Table 1 descriptions are used for generating source code. The HTML Web Page (Microsoft ASP.NET aspx file) is created from the templates that represent the beginning and end of the aspx file; controls such as the TextBox control and Button controls are added after the beginning of file. The principles the generation of the source code is based on are described in the Table 1, and demonstrated by using the productid and the btnShoppingCart descriptions.

The beginning of the aspx file—in this case the product.aspx file—is built from the following template:

```
<%@ Page Title=\”\” Language=\”C#\” MasterPageFile=\”~/Site1.master\”
AutoEventWireup=\”true\” CodeFile=\”@pageName.aspx.cs\” Inherits=\”port85.@pageName\” %>
```

The “@pageName” placeholders are replaced by the form name, “product” The GPU reads the Product description and for each field description checks the controltype field value. With the productid it is the TextBox control that enables an application user to enter the productid value interactively. For generating source code for the productid field, the following TextBox template is used:

```
<asp:TextBox      ID=\"@id\"      runat=\"server\"      OnTextChanged=\"@id_TextChanged\">
</asp:TextBox>
```

The placeholder @id is replaced by productid and added to the product.aspx file:

```
<asp:TextBox                         ID="productid"                          runat="server"
OnTextChanged="productid_TextChanged"></asp:TextBox>
```

To generate source code for btnShoppinCart field, the following Button template is used:

```
<asp:Button  ID=\"@id\"  runat=\"server\"  Height=\"34px\"  Text=\"@text\"  Width=\"184px\"
OnClick=\"@id_Click\" />
```

The placeholder @id is replaced by btnShoppingCart and added to the product.aspx file

```
<asp:Button  ID="btnShoppingCart"  runat="server"  Height="34px"  Text="Shopping  Cart"
Width="184px" OnClick="btnShoppingCart_Click" />
```

The same process is applied to all PRODUCT forms fields and the fields are added to the product.aspx file. The product.aspx file is closed by the `</asp:Content>` end tag.

The ASP.NET architecture can require a generation of the Code-Behind Class; in this case, the `product.aspx.cs` file. The generation of this file is based on the same principles. Generation of this file employs information stored in Table 1 and templates specific for Code-Behind File and the GRA Libraries. The Code-Behind Class shall provide implementation for each of Product form's field events. In the case of the productid field, it is the `productid_TextChanged` event that is called each time the `productid` field contents are changed. The `btnShoppingCart_Click` event is called each time the mouse clicks on the `btnShoppingCart` button. The `productid_TextChanged` and the `btnShoppingCart_Click` methods are generated from the following templates:

```
protected void @id_TextChanged(object sender, EventArgs e)\n{\n

protected void @id_Click(object sender, EventArgs e)\n{\n
```

The @id is replaced by corresponding field name, and each method's declaration is closed by the end method parenthesis `"}\n".` This is the resulting code that is appended to the product.aspx.cs file:

```
        protected void productid_TextChanged(object sender, EventArgs e)
        {
            logUserAction("event=textchanged   ",   "control=productid",   "   value="   +
productid.Text);
        }
protected void btnShoppingCart_Click(object sender, EventArgs e)
{
   logUserAction("event=click ", "control=btnShoppingCart", "");
   Response.Redirect("shoppingcart.aspx?cmdstr=add");
}
```

Either method can be considered implementation-specific. In both methods any kind of C# source code can be inserted.

The `btnShoppingCart_Click` method redirects workflow to the shoppingcart.aspx page, which is an action that is described in the action type column for the btnShoppingCart field.

In the products.aspx.cs file can be inserted any other kind of source code, methods, or declared variable. This is implementation-specific and how the form field will be mapped to the method call is a design and implementation issue.

The GPU also generates the Data Object (DO) Class and SQL statements. It has already been mentioned that the DO Class is used in the context of implementation of Data Access Object pattern (Gamma et al. 1995). The DO Class is used to map relational data to object data and for updating data stored inside of the database tables. Although the Data Object (DO) Class and SQL are represented as two different source code outputs from the GPU as seen in Figure 5, the generated SQL statements can be appended or inserted in any other generated source code files, if necessary.

The process of generating the productDO.cs class is the same as for any other source code file. It uses a class beginning and end template. The following is an example of the source code from a generated productDO.cs class:

```
    public class productDO : AbstractDO
    {
        public string productid;
        public string name;
        public string description;
        public string price;
        public string quantity;
        public string selectedquantity;
        public string btnAddToShoppingCart;
        public string btnShoppingCart;
        public const string DBNAME = “product”;
        public const string PRIMARY_KEY = “productid”;
        public const string PARENT_KEY = “productid”;
        public const string CHILD_KEY = “productid”;
        public productDO(){
         }
        public override string createTable(AbstractDO abstractDO) {
            string  sqlstr  =  “CREATE  TABLE  `product`  (productid  VARCHAR(50),  name
VARCHAR(50),   description   VARCHAR(100),   price   decimal(7,2),   quantity   int(5),
selectedquantity int(5), `tstamp` timestamp NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE
CURRENT_TIMESTAMP ,PRIMARY KEY (productid) ) ENGINE=InnoDB DEFAULT CHARSET=utf8;”;
          return sqlstr;
        }
        public override string dropTable(AbstractDO abstractDO) {
            string sqlstr = “DROP TABLE IF EXISTS “ + DBNAME;
            return sqlstr;
        }
        public override AbstractDO getClassName() {
            return new productDO();
        }
```
Besides each field declaration, the methods and SQL statements that support CRUD operations are located in this class.
Creating a detailed description of this class does not make sense because the GPU implementation as well as the templates and GRA Library methods are all implementation-specific. The implementation presented in this chapter is the author's own design, and this implementation was created for research and experiment purposes. How the requirement description will be structured and where it will be stored is also implementation-specific.

Generating an application without manual programming assumes that the methods are generic and can solve a class of related programming problems. Design patterns (Gamma et al. 1995) can be a great inspiration for designing and writing general purpose methods. Refactoring techniques (Fowler et al. 1999) can be used to learn about improving code reusability. Analyzing design patterns, such as Data Access Object, Abstract Factory (Bulajic and Jovanovic 2012), MVC pattern, and Strategy Pattern, can be useful for designing general purpose methods.

15 Appendix C – Retail Store Example

This chapter introduces an implementation example and the chapter's purpose is to inspire readers and let them perform further research for more specific examples on their own.

The Retail Store application is developed by the Framework that is the implementation of the GRA's high-level design described in Figure 4, in Chapter 6 "Generalized Requirement Approach Framework (GRAF)". Figure 17 illustrates the GRA Framework front-end design:

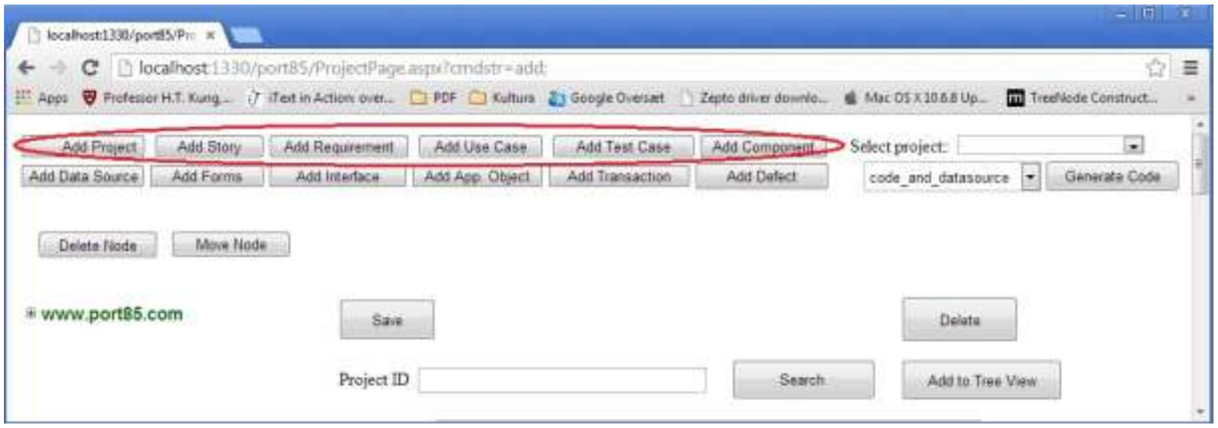
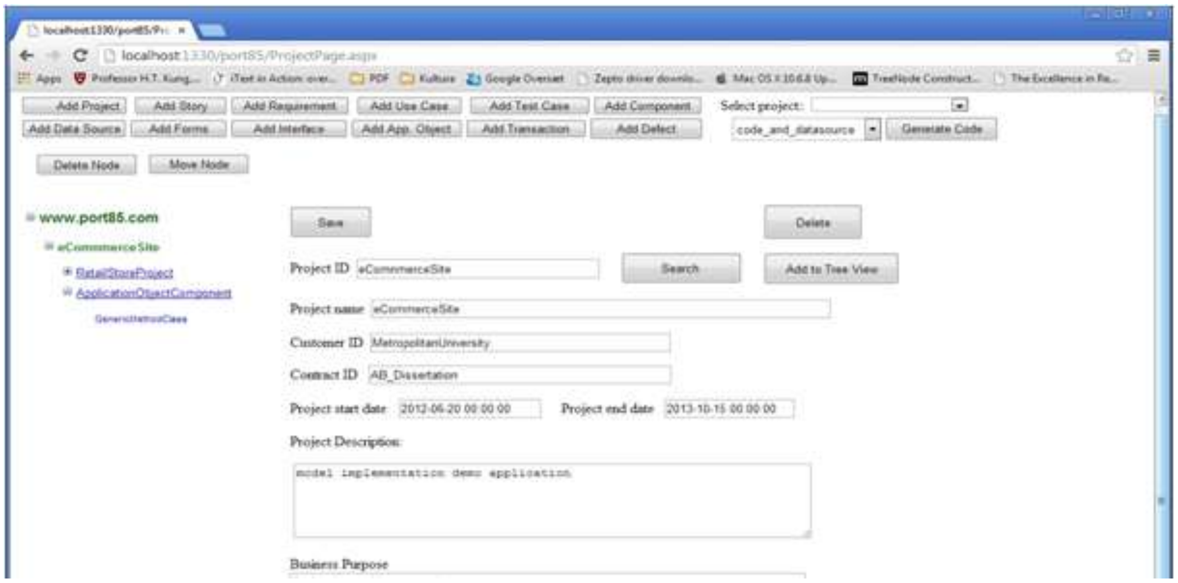


Figure 17 The GRA Framework Implementation v1

The first set of objects, circled in red, is responsible for requirement documenting. The second set of objects, located in the next row following the objects in the red circle, are the objects responsible for storing data in structured text format, which are used to generate source code.

Displayed on the left side of the middle part of the screen are the GRAF objects in the tree view structure. “A tree structure is a powerful tool for storing and manipulating all kind of data, without differences is it used for natural language analysis, compiling computer languages, or storing and analyzing scientific or business data. Algorithms for searching and browsing tree structures are well known, and a numbers of tools for manipulating tree structures are available for free in multiple computer languages” (Bulajic and Filipovic 2012).

Displayed on the right side of the screen is each GRAF object’s attributes. The attributes are guidelines for specifying a sufficient level of details for each of the GRAF objects. Figure 18 illustrates the tree structure on the left side of the screen and the GRAF objects’ attributes on the right side of the screen:



Select project:

code_and_datasource

Project ID: eCommerceSite

Project name: eCommerceSite

Customer ID: MetropolitanUniversity

Contract ID: AB_Dissertation

Project start date: 2012-06-20 00:00:00 Project end date: 2013-10-15 00:00:00

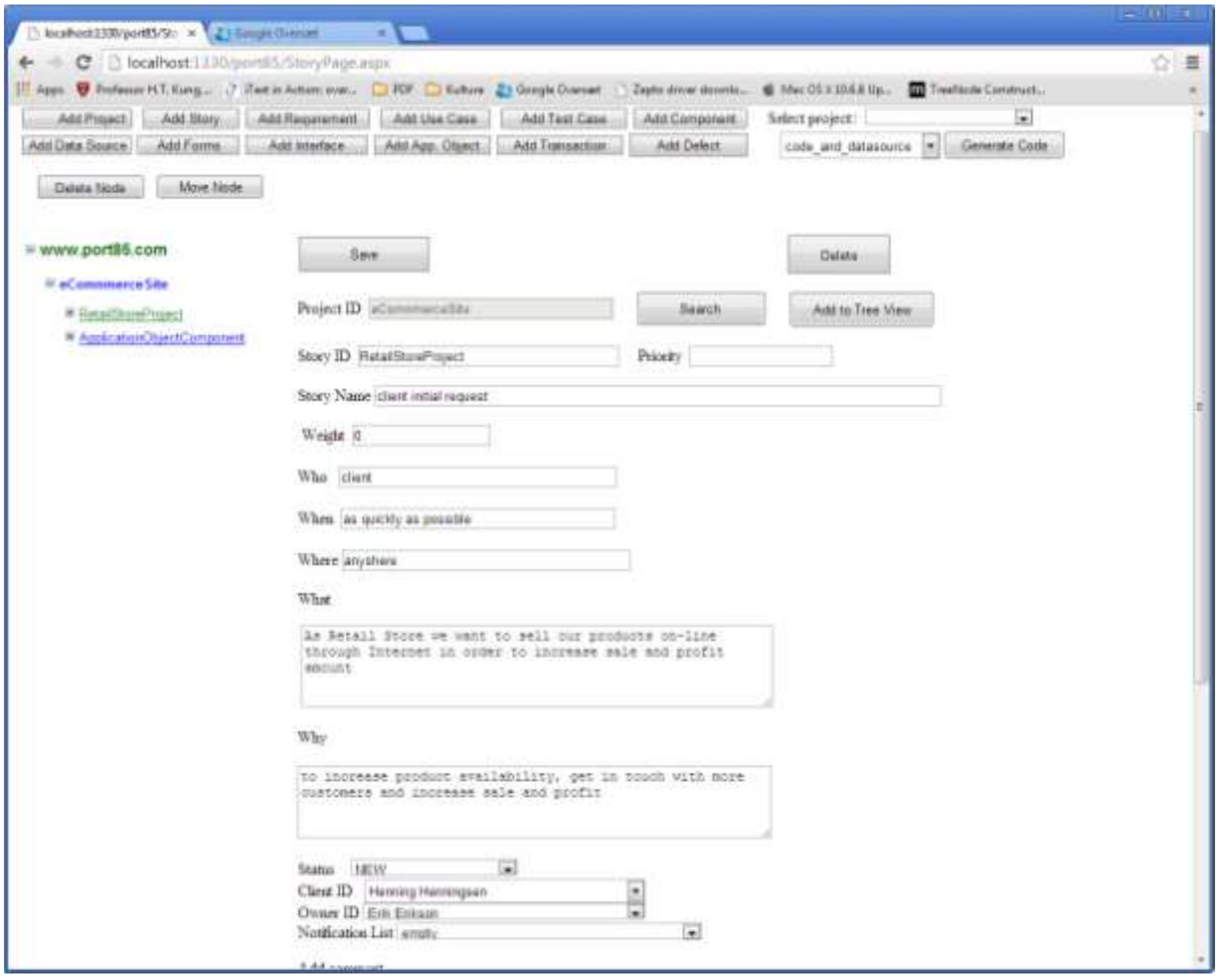
Project Description:

model implementation demo application

Business Purpose

Figure 18 The GRA Framework Front End Design

The implementation of the GRA, the GRA Framework, is tested on the Retail Store application. The Retail Store is a fictive E-Commerce application and is described by the RetailStoreProject User Story in Chapter 7 “GRA Framework Validation”. Figure 19 illustrates the RetailStoreProject User Story:



code_and_datasource

Project ID eCommerceSite

Story ID RetailStoreProject

Priority

Story Name client initial request

Weight 0

Who client

When as quickly as possible

Where anywhere

What

```
As Retail Store we want to sell our products on-line
through Internet in order to increase sale and profit
amount
```

Why

```
to increase product availability, get in touch with more
customers and increase sale and profit
```

Status NEW

Client ID Henning Henningsen

Owner ID Erik Eriksen

Notification List empty

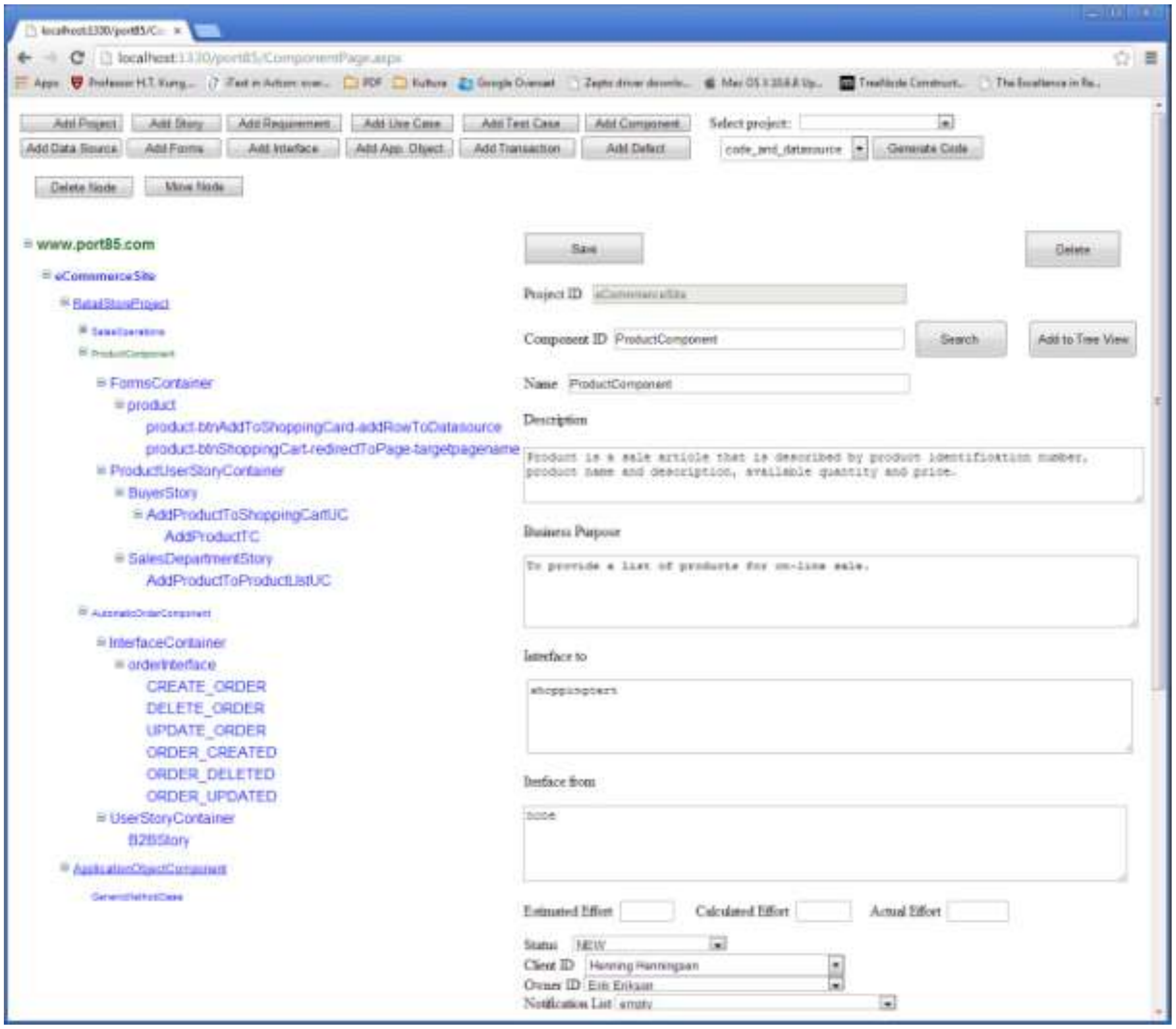
Add comment

Figure 19 Retail Store Project

From the RetailStoreProject User Story is possible to identify:

- ProductComponent object
- Sales Operation

The ProductComponent is described as “a sale article that is described by a product identification number, product name and description, available quantity, and price” and is used “to provide a list of products for on-line sale”. Figure 20 shows all ProductComponent objects:


www.port85.com
eCommerceSite
RetailStoreProject
SalesOperations
ProductComponent
FormsContainer
product
product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomaticOrderComponent
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
GenericMethodCase

Project ID: eCommerceSite
Component ID: ProductComponent
Name: ProductComponent
Description:
```
Product is a sale article that is described by product identification number,
product name and description, available quantity and price.
```
Business Purpose:
```
To provide a list of products for on-line sale.
```
Interface to:
```
shoppingcart
```
Interface from:
```
none
```
Estimated Effort: Calculated Effort: Actual Effort:
Status: NEW
Client ID: Henning Henningsen
Owner ID: Eric Eriksen
Notification List: empty

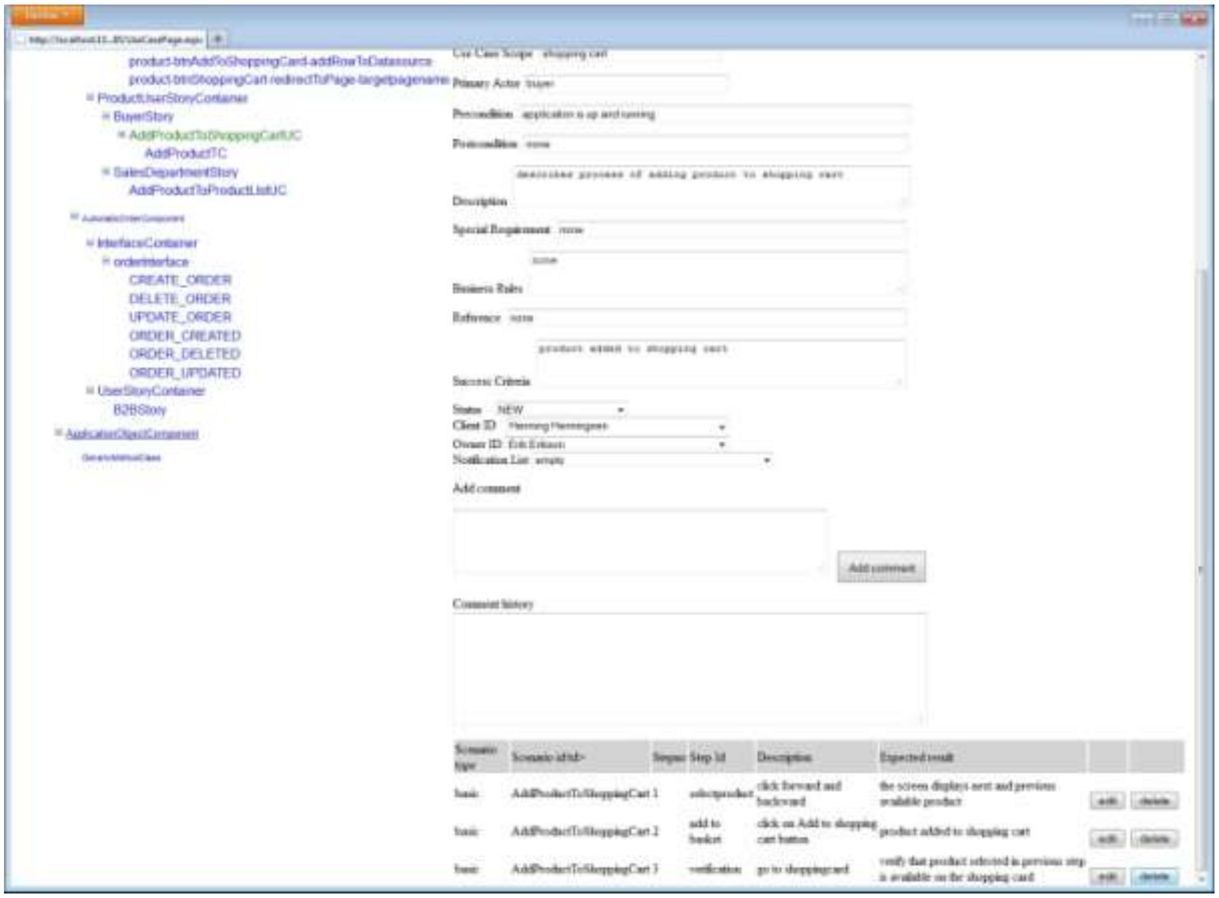
Figure 20 Product Component

The ProductComponent contains:

- FormsContainer
- UserStoryContainer

These two containers are used for storing Forms design information and the User Story, SalesDepartmentStory, and AddProductToShoppingCartUC Use Cases.

In the SalesDepartmentStory described in Chapter 7 “GRA Framework validation” are the Sales Department and Salesman expectations. The SalesDepartmentStory is described in more detail by the AddProductToProductListUC Use Case. Figure 21 illustrates the Use Case template and guidelines and reveals more details about the Product object:



product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomaticOrderComponent
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
GenericMethodClass

Use Case Scope	shopping cart
Primary Actor	buyer
Precondition	application is up and running
Postcondition	none
Description	describes process of adding product to shopping cart
Special Requirement	none
Business Rules	none
Reference	none
Success Criteria	product added to shopping cart
Status	NEW
Client ID	Henning Henningsen
Owner ID	Erik Eriksen
Notification List	empty

Add comment

Comment history

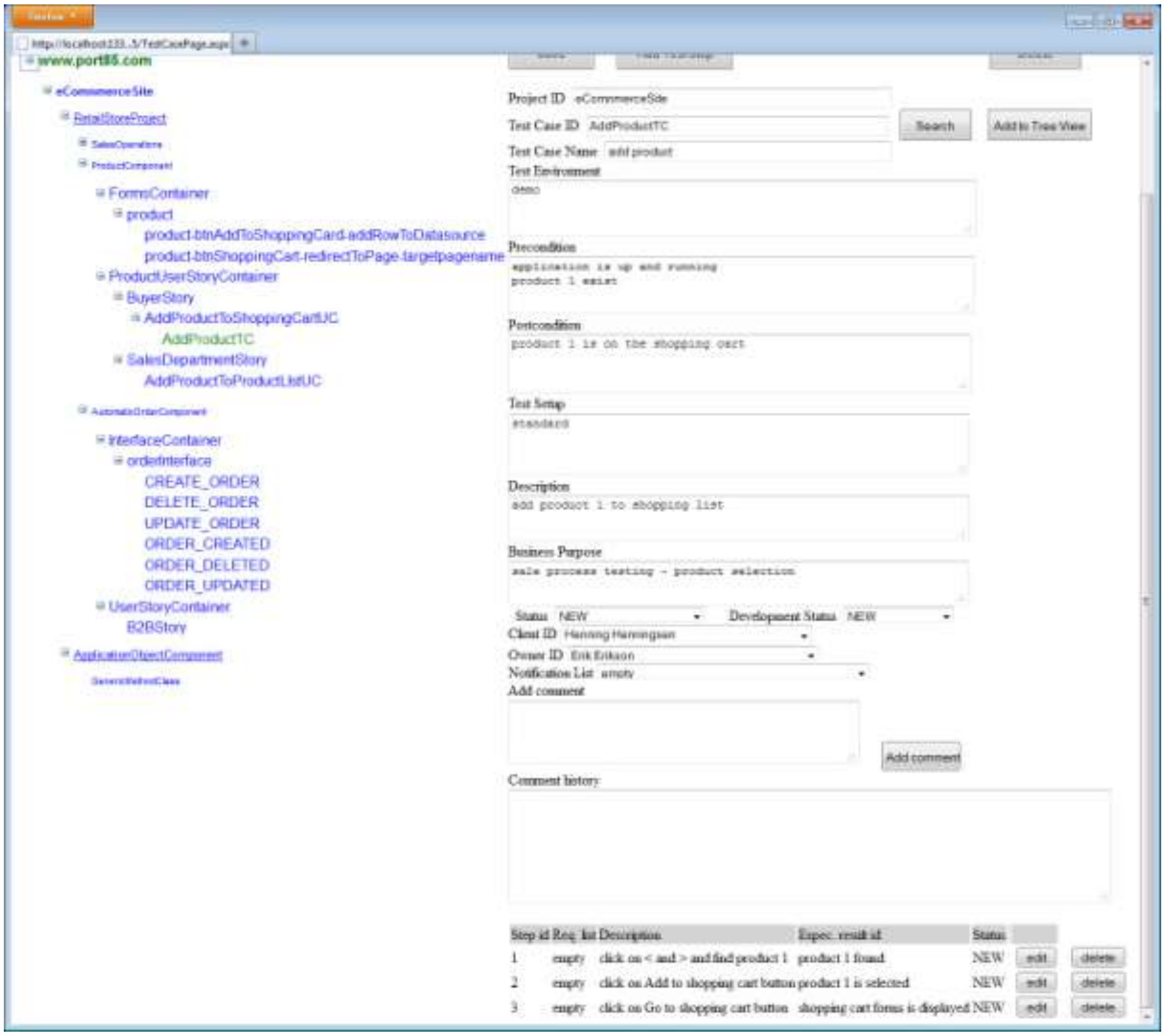
Scenario type	Scenario id\td>	Stepno	Step Id	Description	Expected result		
basic	AddProductToShoppingCart	1	selectproduct	click forward and backward	the screen displays next and previous available product	edit	delete
basic	AddProductToShoppingCart	2	add to basket	click on Add to shopping cart button	product added to shopping cart	edit	delete
basic	AddProductToShoppingCart	3	verification	go to shoppingcard	verify that product selected in previous step is available on the shopping card	edit	delete

Figure 21 AddProductToShoppingCartUC Use Case

Described in the AddProductToShoppingCartUC Use Case are all the steps and the order of execution to add a product to the shopping list. The Use Case object is a template and guideline for creating a Use Case. The Framework enables a user to add a new step, or update or delete an existing step feature.

If it is necessary to review why this Use Case is essential, a mouse click on the parent node, BuyerStory, will explain it to the user. The BuyerStory User Story is reused in the ShoppinCartComponent. This will be demonstrated later. Although this User Story is assigned to two different nodes and components, there is only one instance of this story. It means that any BuyerStory changes will be reflected to all nodes. While this feature is an advantage for documentation, it can create a side effect of defects, because changes will affect an unknown number of objects.

Figure 22 illustrates the Test Case template and guidelines:



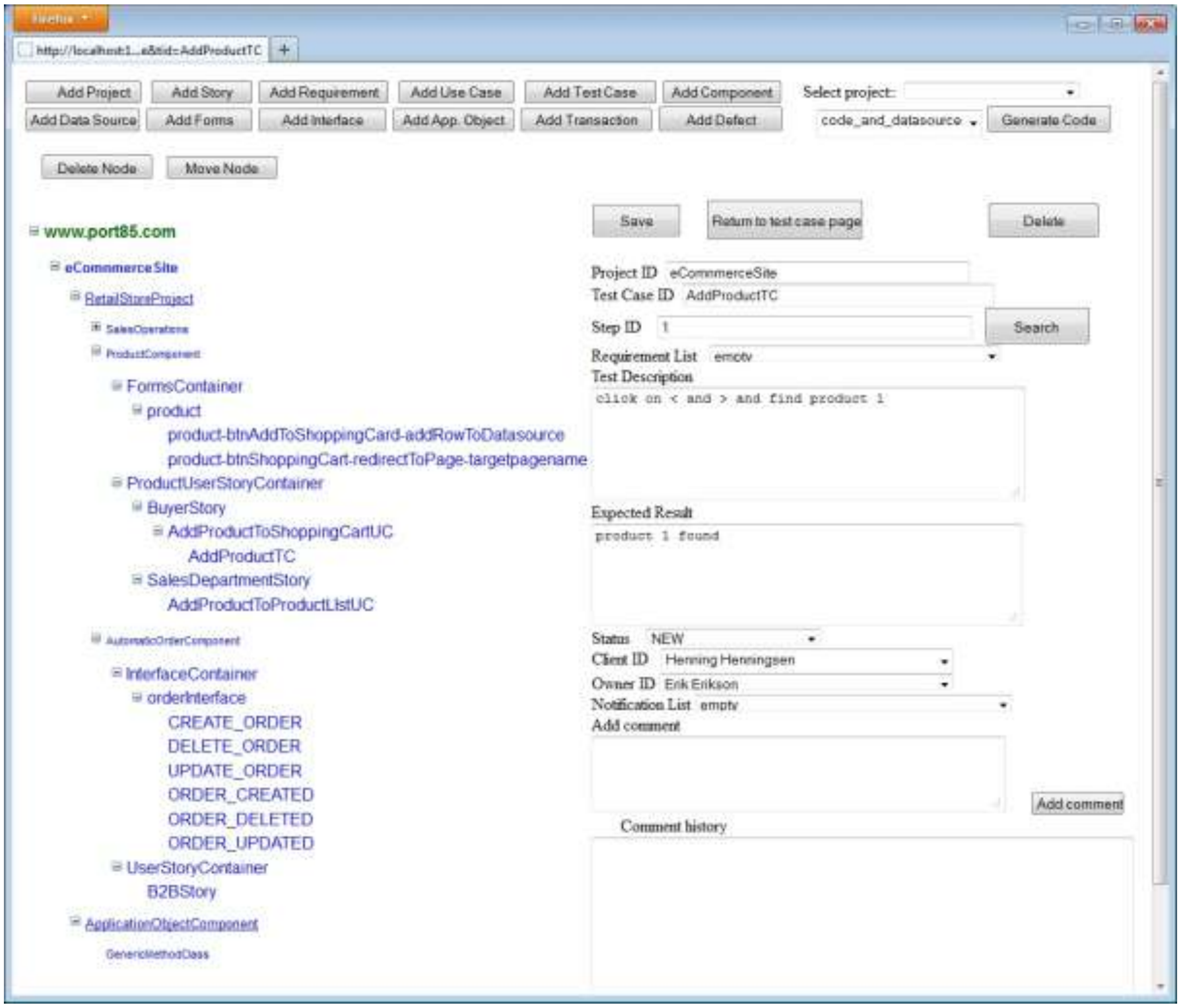
Project ID eCommerceSite
Test Case ID AddProductTC
Test Case Name add product
Test Environment
demo
Precondition
application is up and running
product 1 exist
Postcondition
product 1 is on the shopping cart
Test Setup
standard
Description
add product 1 to shopping list
Business Purpose
sale process testing - product selection
Status NEW Development Status NEW
Client ID Henning Henningsen
Owner ID Erik Eriksson
Notification List empty
Add comment
Comment history

Step id	Req. list	Description	Expec. result id	Status
1	empty	click on < and > and find product 1	product 1 found	NEW
2	empty	click on Add to shopping cart button	product 1 is selected	NEW
3	empty	click on Go to shopping cart button	shopping cart forms is displayed	NEW

Figure 22 AddProductTC Test Case

The Test Case template and guidelines provide information about the Test Case's purpose as well as describing details about each Test Case step.

The Test Case and Test Case step's objects provide a standard set of database operations, such as insert, update, delete, and search. It is possible to copy a Test Case or Test Step by changing the ID and Use Save option. Figure 23 illustrates the Test Case template and guidelines:



Select project:
code_and_datasource

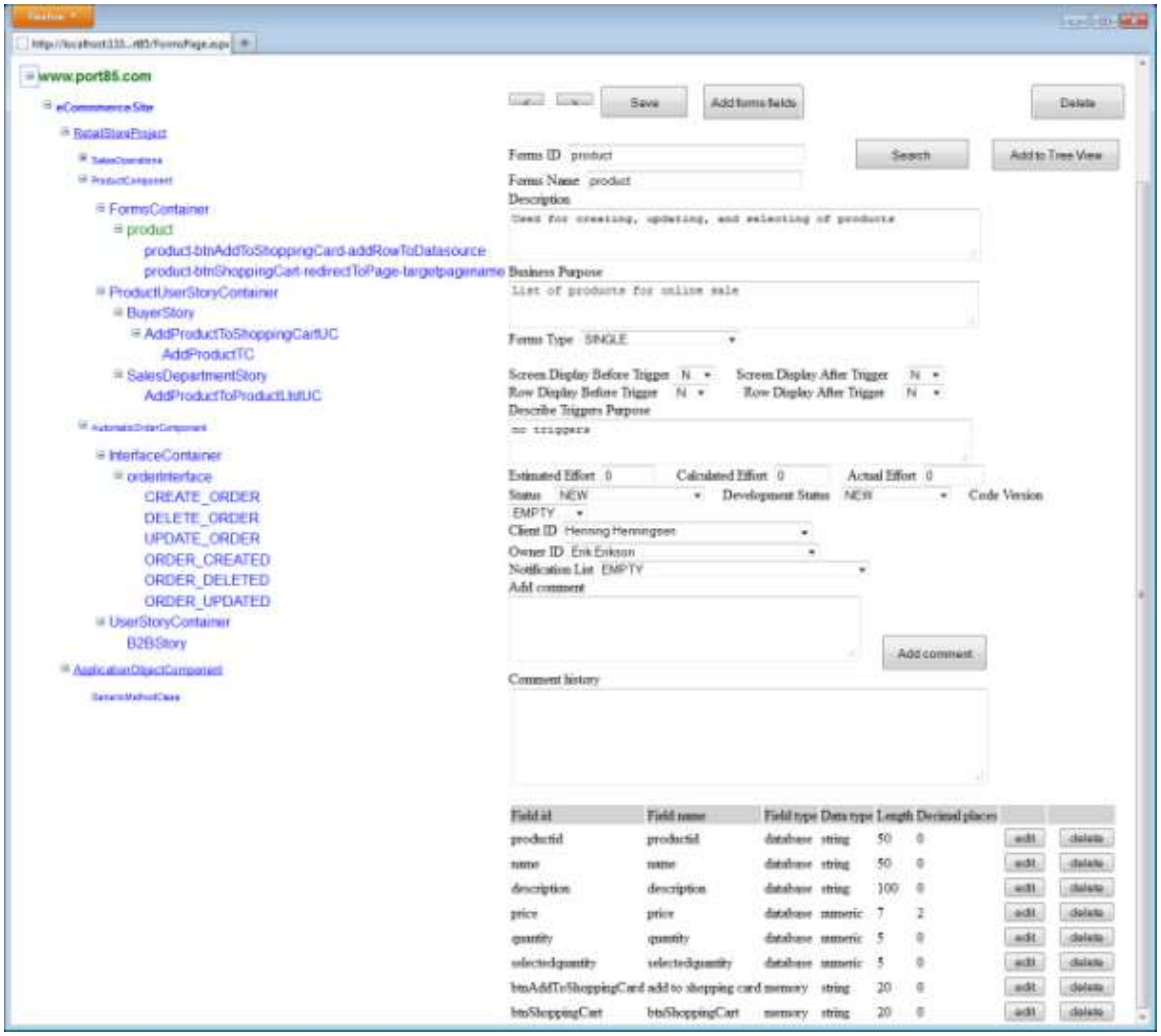
- www.port85.com
  - eCommmerceSite
    - RetailStoreProject
      - SalesOperations
      - ProductComponent
        - FormsContainer
          - product
            - product-btnAddToShoppingCard-addRowToDatasource
            - product-btnShoppingCart-redirectToPage-targetpagename
        - ProductUserStoryContainer
          - BuyerStory
            - AddProductToShoppingCartUC
              - AddProductTC
          - SalesDepartmentStory
            - AddProductToProductListUC
      - AutomaticOrderComponent
        - InterfaceContainer
          - orderInterface
            - CREATE_ORDER
            - DELETE_ORDER
            - UPDATE_ORDER
            - ORDER_CREATED
            - ORDER_DELETED
            - ORDER_UPDATED
        - UserStoryContainer
          - B2BStory
    - ApplicationObjectComponent
      - GenericMethodClass

Project ID: eCommmerceSite
Test Case ID: AddProductTC
Step ID: 1
Requirement List: empty
Test Description:
```
click on < and > and find product 1
```
Expected Result:
```
product 1 found
```
Status: NEW
Client ID: Henning Henningsen
Owner ID: Erik Erikson
Notification List: empty
Add comment
Comment history

Figure 23 AddProductTC Test Step

The Framework enables adding, moving, and deleting each object or node. The deletion of a node will update tree view, but the node's description and corresponding node object will still exist and can be reused by another node

The ProductComponent contains the FormsContainer node. The FormsContainer in this implementation is used for design structuring purposes. While the previously mentioned objects are used for design and documenting purposes, the Forms object is used by the Generator to generate source code and executables. Figure 24 illustrates the Forms objects template and guidelines:



Forms ID product
Forms Name product
Description
Used for creating, updating, and selecting of products
Business Purpose
List of products for online sale
Forms Type SINGLE
Screen Display Before Trigger N   Screen Display After Trigger N
Row Display Before Trigger N   Row Display After Trigger N
Describe Triggers Purpose
no triggers
Estimated Effort 0   Calculated Effort 0   Actual Effort 0
Status NEW   Development Status NEW   Code Version EMPTY
Client ID Henning Henningsen
Owner ID Erik Erikson
Notification List EMPTY
Add comment
Comment history

Field id	Field name	Field type	Data type	Length	Decimal places		
productid	productid	database	string	50	0	edit	delete
name	name	database	string	50	0	edit	delete
description	description	database	string	100	0	edit	delete
price	price	database	numeric	7	2	edit	delete
quantity	quantity	database	numeric	5	0	edit	delete
selectedquantity	selectedquantity	database	numeric	5	0	edit	delete
btnAddToShoppingCard	add to shopping card	memory	string	20	0	edit	delete
btnShoppingCart	btnShoppingCart	memory	string	20	0	edit	delete

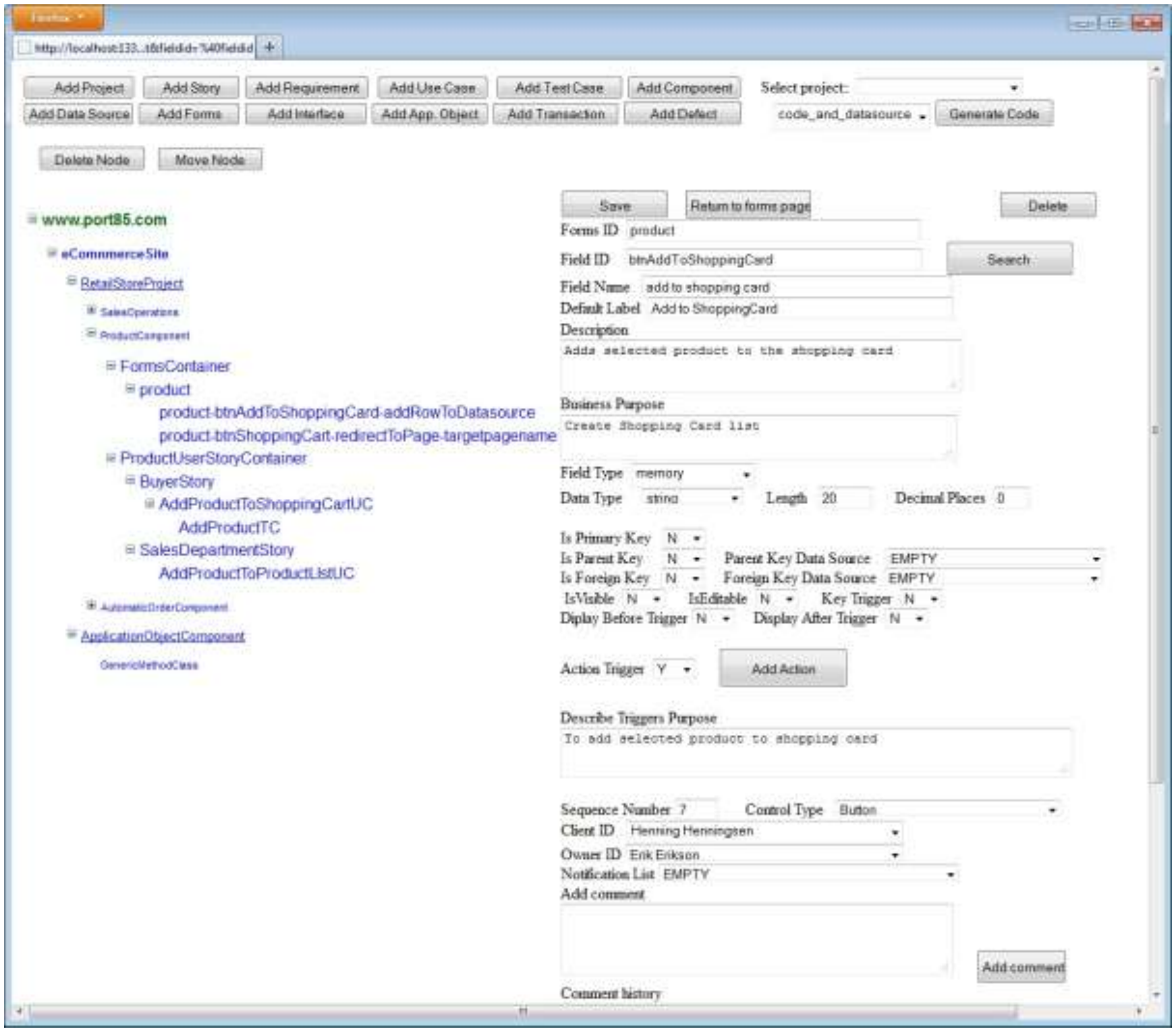
Figure 24 ProductForms Forms

The decision about where in the hierarchy to put a Forms object can be important for a better design understanding. For experimental purposes, the product Forms is assigned to the FormsContainer. Another possibility would be to add product forms to the User Story or Use Case node. The product forms can be described by more than one User Story and Use Case. To resolve the M:N (many to many) relationship within database modeling, it is necessary to create a complex entity that contains IDs from both involved entities. Under the circumstances of the tree structure this relationship should not be an issue as long as the same product form is a unique object. This means that there is only one instance of the same product forms stored in the permanent storage. Here it is possible to assign product forms as top level nodes and assign related User Stories, Use Cases and Test Cases to the descendent nodes. This can be considered upside-down logic, because the User Stories specify a Forms object.

This dilemma is not easy to resolve and it illustrates the need for different views of the same design structure. Different views and design structure transformations improve the system's understanding and relations between objects and structures. The tree structure's transformation capability fits well to these requirements.

In this case, the design choice has been driven by requirements to clearly demonstrate method implementation and the Framework's objects. That is the reason why it was necessary to create the FormsContainer to demonstrate the Forms object templates and guidelines.

The Forms object describes forms fields, field's type and length, and a set of triggers that can be assigned to the forms level and to the each forms field. While the field's purpose is to accept user inputs and commands, triggers represent processing actions that software products should execute after the rising of event. These events can be raised on the forms level or on the field level. These actions can be simple, such as redirecting a Web page to another URL, but they can also be complex and can require complex algorithms, access to the complex data structures and relations, and require complex validation. Figure 25 illustrates the template and guideline for defining form fields:



http://localhost133...t&fieldid=%40fieldid

Select project:
code_and_datasource

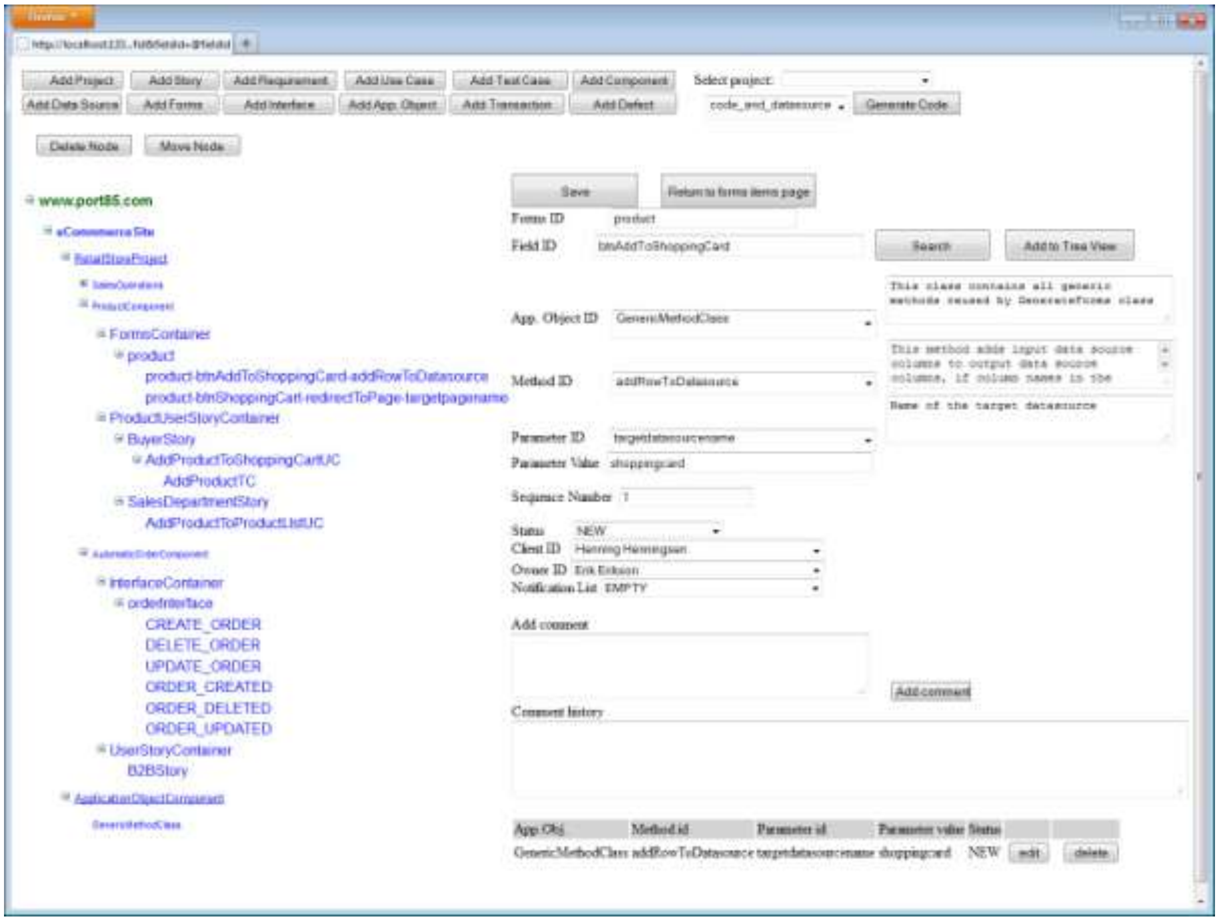
www.port85.com
eCommerceSite
RetailStoreProject
SalesOperations
ProductComponent
FormsContainer
product
product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomaticOrderComponent
ApplicationObjectComponent
GenericMethodClass

Forms ID product
Field ID btnAddToShoppingCard
Field Name add to shopping card
Default Label Add to ShoppingCard
Description
Adds selected product to the shopping card
Business Purpose
Create Shopping Card list
Field Type memory
Data Type string Length 20 Decimal Places 0
Is Primary Key N
Is Parent Key N Parent Key Data Source EMPTY
Is Foreign Key N Foreign Key Data Source EMPTY
IsVisible N IsEditable N Key Trigger N
Diplay Before Trigger N Display After Trigger N
Action Trigger Y
Describe Triggers Purpose
To add selected product to shopping card
Sequence Number 7 Control Type Button
Client ID Henning Henningsen
Owner ID Erik Erikson
Notification List EMPTY
Add comment
Comment history

Figure25 Product Forms Fields

The Forms field's description provides information about field data type, field size, field type—such as a database or a memory field—and what the Generator uses to decide if it is necessary to provide a place for a field value in the permanent storage or if it is a temporary variable that will disappear after processing. There are a number of Y/N options that provide detailed information about a field's significance, visibility, field validation and lookup data sources, and about triggers and actions, as well as the control type used to create a field's representation in the Forms object. The control type is important not only because of the design issues, but also because the control type decides what kind of events can be assigned to a particular control type. For example, in the case of Microsoft .NET, it is possible to assign to the Button control an OnClick event, but this kind of event does not exist in the event of the TextBox control.

Figure 26 illustrates the Add Action to Forms Fields template and guidelines:



Select project:	
	code_and_datasource
Forms ID	product
Field ID	btnAddToShoppingCard
App. Object ID	GenericMethodClass
Method ID	addRowToDatasource
Parameter ID	targetdatasourcename
Parameter Value	shoppingcard
Sequence Number	1
Status	NEW
Client ID	Henning Henningsen
Owner ID	Erik Eriksson
Notification List	EMPTY
Add comment	
Comment history	

```
This class contains all generic
methods reused by GenerateForms class
```

```
This method adds input data source
columns to output data source
columns, if column names in the
```

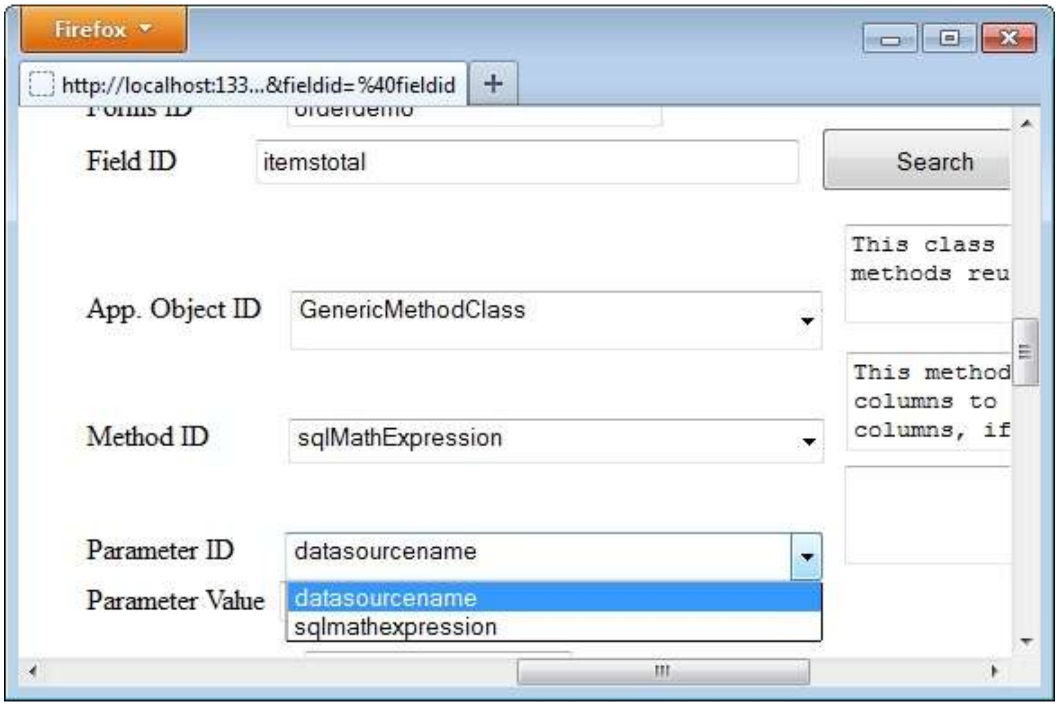
```
Name of the target datasource
```

App Obj	Method id	Parameter id	Parameter value	Status		
GenericMethodClass	addRowToDatasource	targetdatasourcename	shoppingcard	NEW	edit	delete

Figure 26 Add Action addRowToDataSource

The Forms ID and Field ID are forms and forms fields' unique identifiers. The App. Object ID, Method ID, and Parameter ID are class, method, and parameter identifiers. The Generator translates this to the code that is assigned to the forms fields and is executed when an event on that field is fired. In this particular case when a click event is fired on the btnAddToShoppingCart fields, it will call upon an addRowToDatasource method and this method's parameter, targetdatasourcename, will be set to the "shoppingcart" value.

When a method requires more parameters, the Parameter ID dropdown list contains the parameter list and to each parameter it is possible to add a field or a value. This is illustrated in Figure 27:



Forms ID: orderdemo
Field ID: itemstotal
App. Object ID: GenericMethodClass
Method ID: sqlMathExpression
Parameter ID: datasourcename
Parameter Value

datasourcename
sqlmathexpression

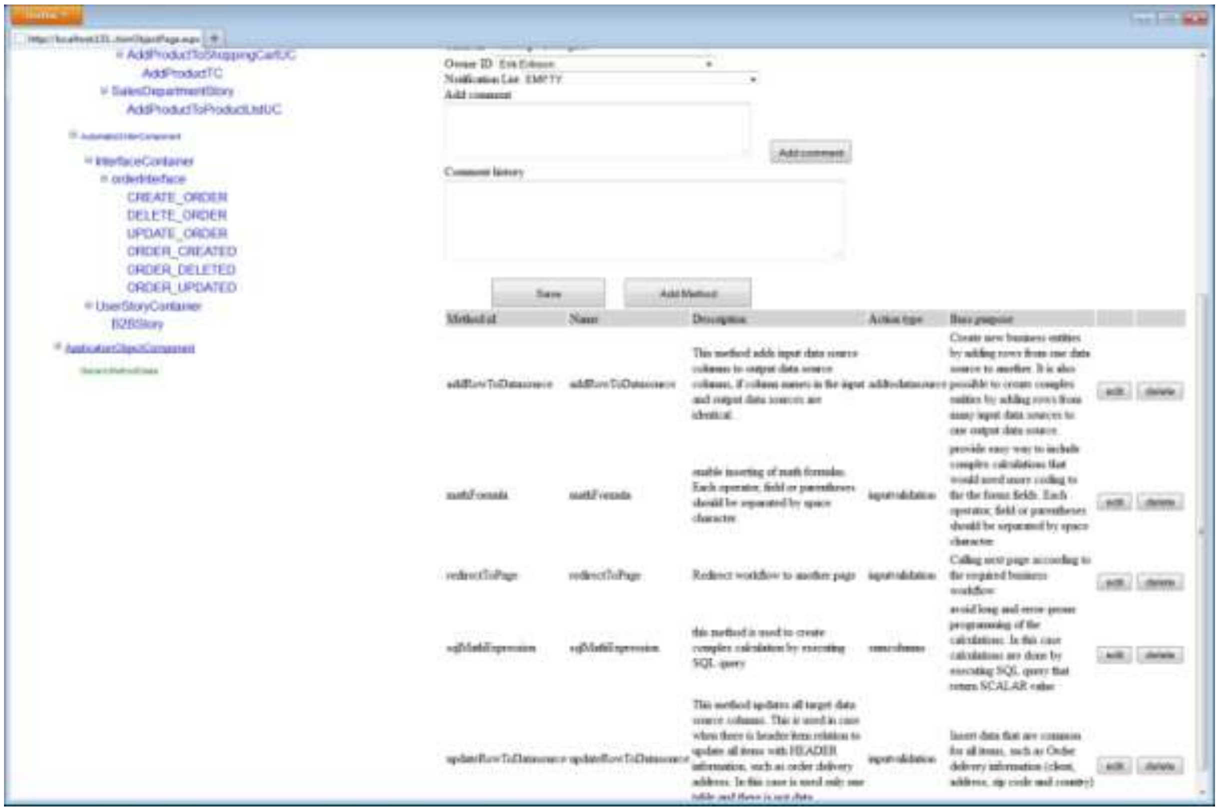
This class
methods reu

This method
columns to
columns, if

Figure 27Add Action Parameter List

This is a straightforward process and is guided by the Framework's ApplicationObject object and applicationobjectmethodsparameters_formsfields entity. In the above example, the sqlMathExpression requires two parameters: the first parameter is datasourcename and the second parameter is sqlmathexpression.

Figure 28 illustrates the generic methods used for creating an example application:



AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductListUC
AutomatedInterComponent
InterfaceContainer
orderInterface
CREATE_ORDER
DELETE_ORDER
UPDATE_ORDER
ORDER_CREATED
ORDER_DELETED
ORDER_UPDATED
UserStoryContainer
B2BStory
ApplicationObjectComponent
GenericMethodClass

Owner ID: Erik Eriksson
Notification List: EMPTY
Add comment
Comment history

Method id	Name	Description	Action type	Bus purpose		
addRowToDatasource	addRowToDatasource	This method adds input data source columns to output data source columns, if column names in the input and output data sources are identical.	addtodatasource	Create new business entities by adding rows from one data source to another. It is also possible to create complex entities by adding rows from many input data sources to one output data source.	edit	delete
mathFormula	mathFormula	enable inserting of math formulas. Each operator, field or parentheses should be separated by space character	inputvalidation	provide easy way to include complex calculations that would need more coding to the the forms fields. Each operator, field or parentheses should be separated by space character	edit	delete
redirectToPage	redirectToPage	Redirect workflow to another page	inputvalidation	Calling next page according to the required business workflow	edit	delete
sqlMathExpression	sqlMathExpression	this method is used to create complex calculation by executing SQL query	[illegible]	avoid long and error prone programming of the calculations. In this case calculations are done by executing SQL query that return SCALAR value	edit	delete
updateRowToDatasource	updateRowToDatasource	This method updates all target data source columns. This is used in case when there is header item relation to update all items with HEADER information, such as order delivery address. In this case is used only one table and there is not data	inputvalidation	Insert data that are common for all items, such as Order delivery information (client, address, zip code and country)	edit	delete

Figure 28 ApplicationObject Component GenericMethodClass

To be able to execute method and assign parameters, the class and method should already exist. Another requirement is that class and method should be generic and should adapt the execution to parameter values.

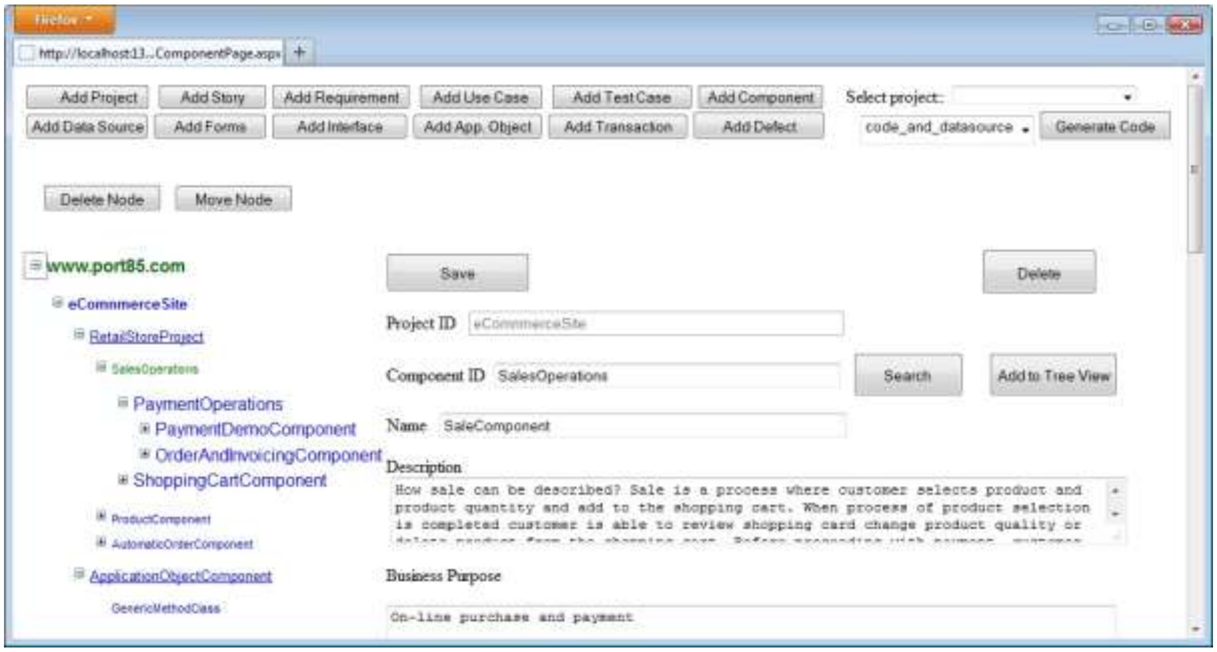
To build this example application, research identified following the five procedures:

- addRowToDatasource – adds current objects' data to the output data source. Used to add product to the ShoppingCart as well as for adding ShoppingCart items to Order,
- updateRowToDatasource – updates row in the database by using current object data. Used to update Order with delivery info.
- sqlMathExpression – for calculation based on the data stored in the SQL tables. Used for calculating the total price of the product items,
- mathFormula – calculation based on math operations. Used for calculations that can be expressed by implementation language notation and available mat functions, and is executed on the numeric data stored in the application internal memory. In this particular case, it is used for calculating the Order's total amount,
- redirectToPage – moves workflow to the next Web page. Used for navigation purposes and changing application workflow

Writing the redirectToPage method in generic code is a simple task, because this method needs a target page name and eventual parameters list. Writing the math Formula, however, requires more time to be designed to remove the complexity and the sqlMathExpression needs more effort to make the method reusable,

The real complex methods for most programmers are algorithms where detailed data model relations are involved. To reduce this kind of complexity, the data model built by the Generator is simple and this model is not normalized. Normalization and entity relations increase the processing complexity and require access to multiple tables, storing and keeping track of temporary results, and enabling transaction management. In the case of the GRA Framework implementation, the simplicity is the preferred approach. Data normalization, code optimization, and security, according to this method, were moved to the next step where developer specialists and experts are involved for each task.

The steps in the ProductComponent design demonstrate the design process and the use of the Framework's objects. The tree view is built from the predefined set of objects and each node description is a template that provides the sufficient number of details for specifying each selected object. The SalesOperation component design is illustrated in Figure 29:



Select project:

code_and_datasource

Project ID: eCommerceSite

Component ID: SalesOperations

Name: SaleComponent

Description

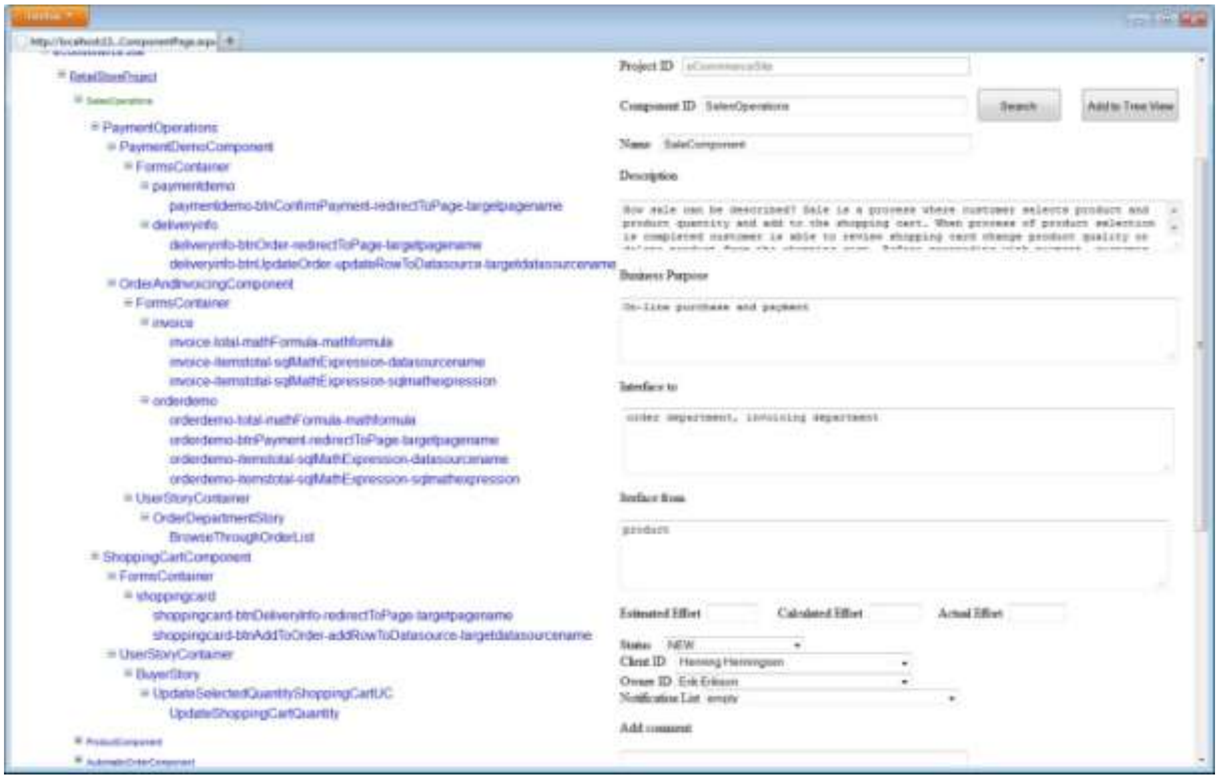
```
How sale can be described? Sale is a process where customer selects product and
product quantity and add to the shopping cart. When process of product selection
is completed customer is able to review shopping card change product quality or
```

Business Purpose

```
On-line purchase and payment
```

Figure 29 SalesOperation Component

The SalesOperation component contains the PaymentOperations and ShoppingCartComponent. The PaymentOperations component contains the PaymentDemoComponent and ShoppingCartComponent. These components are built using the same Framework objects as the ProductComponent. Figure 30 illustrates these components' internal design:



```
⊟ RetailStoreProject
  ⊟ SalesOperations
    ⊟ PaymentOperations
      ⊟ PaymentDemoComponent
        ⊟ FormsContainer
          ⊟ paymentdemo
              paymentdemo-btnConfirmPayment-redirectToPage-targetpagename
          ⊟ deliveryinfo
              deliveryinfo-btnOrder-redirectToPage-targetpagename
              deliveryinfo-btnUpdateOrder-updateRowToDatasource-targetdatasourcename
      ⊟ OrderAndInvoicingComponent
        ⊟ FormsContainer
          ⊟ invoice
              invoice-total-mathFormula-mathformula
              invoice-itemstotal-sqlMathExpression-datasourcename
              invoice-itemstotal-sqlMathExpression-sqlmathexpression
          ⊟ orderdemo
              orderdemo-total-mathFormula-mathformula
              orderdemo-btnPayment-redirectToPage-targetpagename
              orderdemo-itemstotal-sqlMathExpression-datasourcename
              orderdemo-itemstotal-sqlMathExpression-sqlmathexpression
        ⊟ UserStoryContainer
          ⊟ OrderDepartmentStory
              BrowseThroughOrderList
    ⊟ ShoppingCartComponent
      ⊟ FormsContainer
        ⊟ shoppingcard
            shoppingcard-btnDeliveryInfo-redirectToPage-targetpagename
            shoppingcard-btnAddToOrder-addRowToDatasource-targetdatasourcename
      ⊟ UserStoryContainer
        ⊟ BuyerStory
          ⊟ UpdateSelectedQuantityShoppingCartUC
              UpdateShoppingCartQuantity
  ⊞ ProductComponent
  ⊞ AutomaticOrderComponent
```

Project ID: eCommerceSite

Component ID: SalesOperations

Name: SaleComponent

Description:

```
How sale can be described? Sale is a process where customer selects product and
product quantity and add to the shopping cart. When process of product selection
is completed customer is able to review shopping cart change product quality or
```

Business Purpose:

```
On-line purchase and payment
```

Interface to:

```
order department, invoicing department
```

Interface from:

```
product
```

Estimated Effort: Calculated Effort: Actual Effort:

Status: NEW

Client ID: Henning Henningsen

Owner ID: Erik Eriksson

Notification List: empty

Add comment

Figure 30 SalesOperation Component Design Details

The FormsContainer in the PaymentDemoComponent contains two different forms objects, paymentdemo forms and deliveryinfo forms. The reason for two forms is that payment options require the provision of a delivery address (deliveryinfo forms) and credit card details (paymentdemo forms).

The OrderAndInvoiceComponent contains the Order and Invoice components. In a real-life project these two components are separated. The reason to keep these two together here is to simplify the example application.

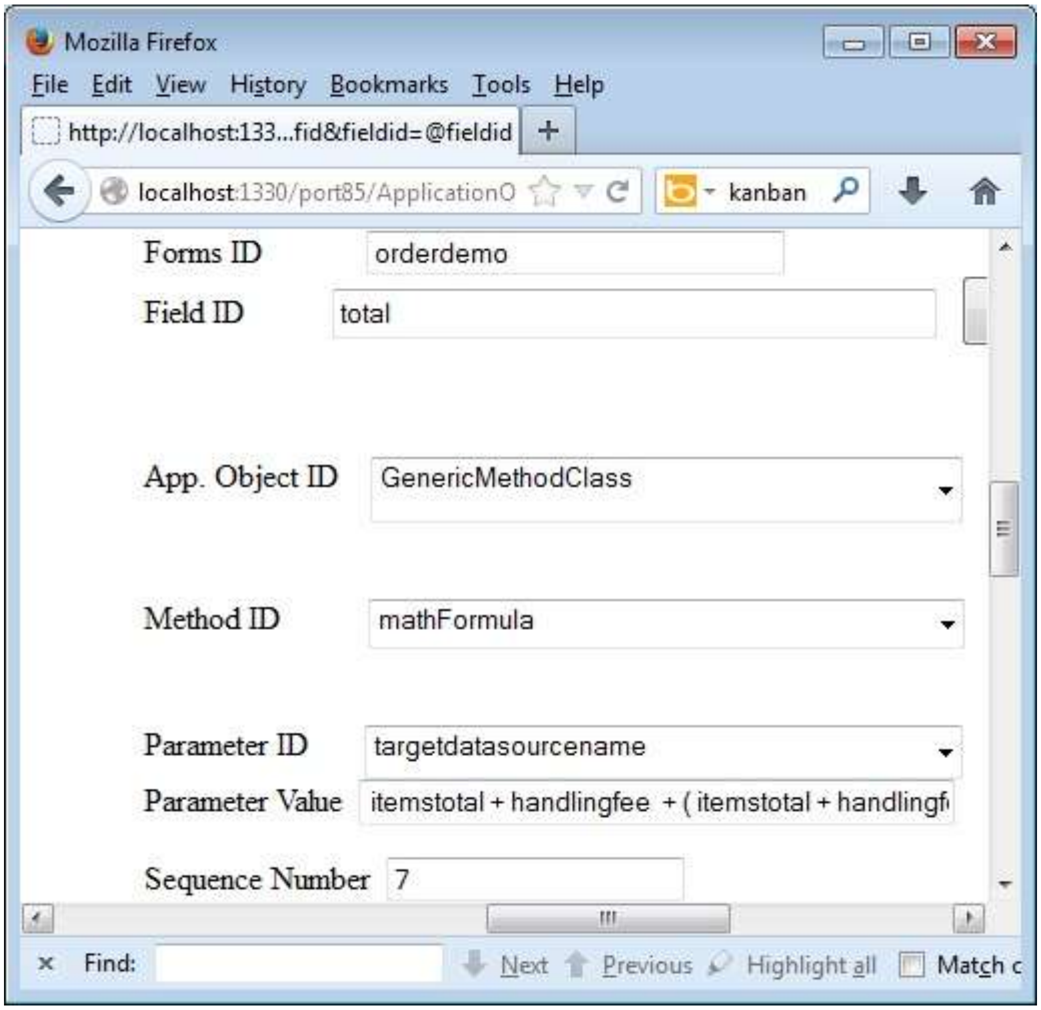
The last step in this process is generating source code and executables. Generated source code and executables are used for requirement validation, and any further work is directly dependent on the validation results. The Generator already utilizes a defined object from the design components. The forms are used for requirement visualization, test, and validation of future product features. The generated source code and executables are used to validate a sufficient level of detail.

For example, the mathFormula assigned to the orderdemo forms total field is described as "*itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100*"

If any of the operands is missing, the compiler will issue an error.

If any of operand contains an illegal value, such as a null value, the compiler will issue an error.

If there are no compiler errors, the executables will enable testing of the math formula by assigning different values to each or a selected number of operands, and display the calculation results. Figure 31 illustrates the orderdemo forms design:


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:133...fid&fieldid=@fieldid
localhost:1330/port85/ApplicationO
kanban
Find:
Next
Previous
Highlight all
Match c

Forms ID	orderdemo
Field ID	total
App. Object ID	GenericMethodClass
Method ID	mathFormula
Parameter ID	targetdatasourcename
Parameter Value	itemstotal + handlingfee + (itemstotal + handlingfi
Sequence Number	7

Figure 31 Math Formula Example

To enable validation, it is necessary to generate source code and executables. This job is accomplished by the Generator. The Generator reads each Framework object design's information and translates it to the C# source code. Before the Generator is involved the desired design object and Generator options should be selected, and then the Generator is involved with a single click on the Generate Code button.

Figure 32 illustrates this button position and options:

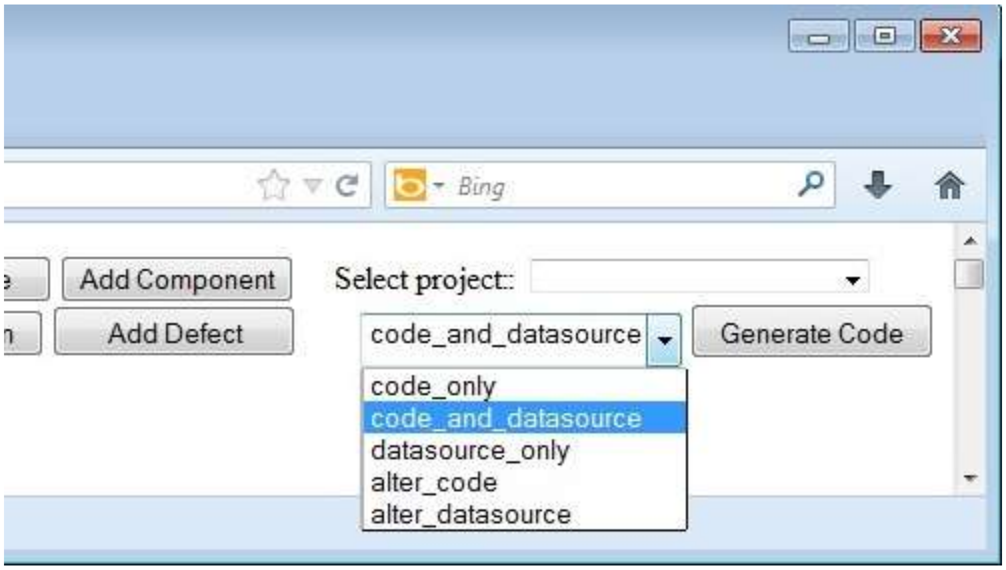


Figure 32 Generate Code

In the dropdown list are the options for creating code_only, code_and_datasource, datasource_only, or for altering code and data source. This version of the Framework implements the two first options, code_only and code_and_datasource options.

When each of the Forms is selected and generated, the Framework will redirect workflow to the generated page. Figure 33 illustrates the Generate Code result:

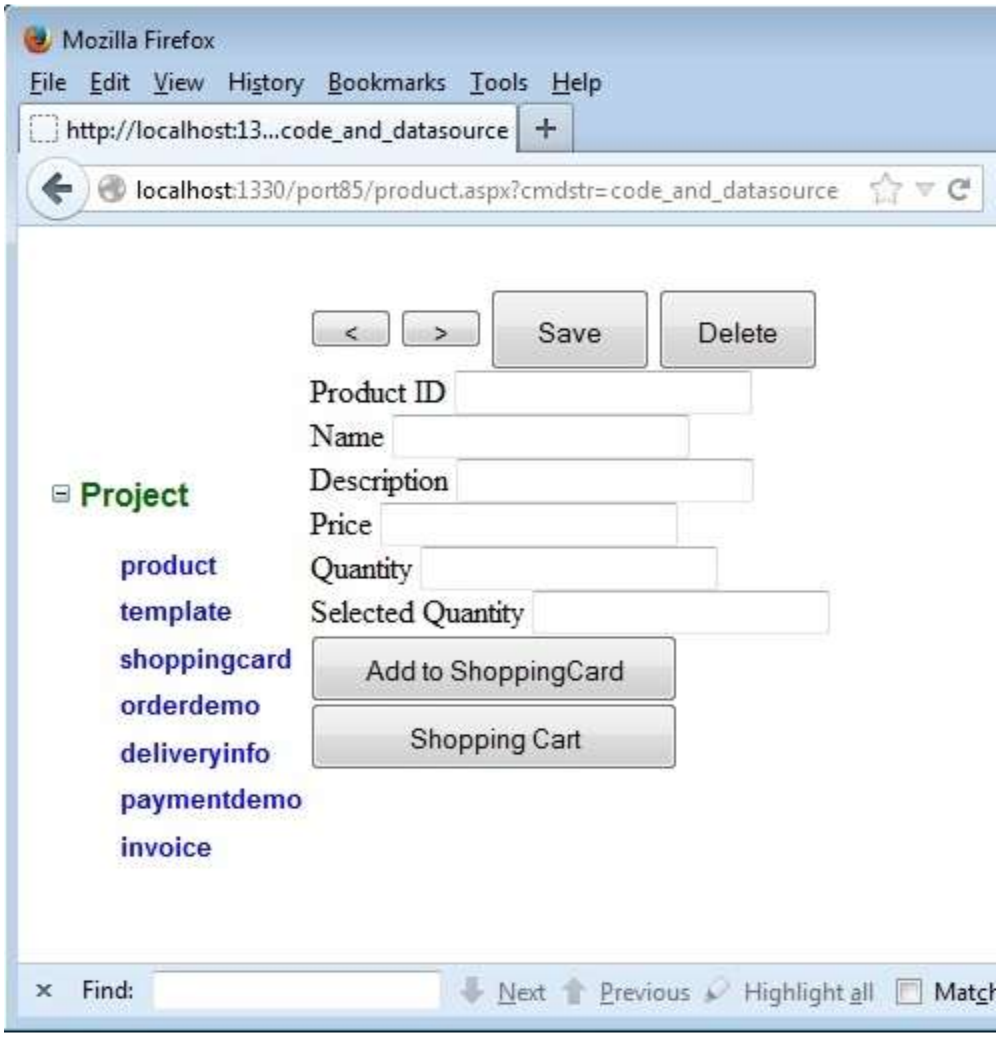


Figure 33 Product Forms Generated

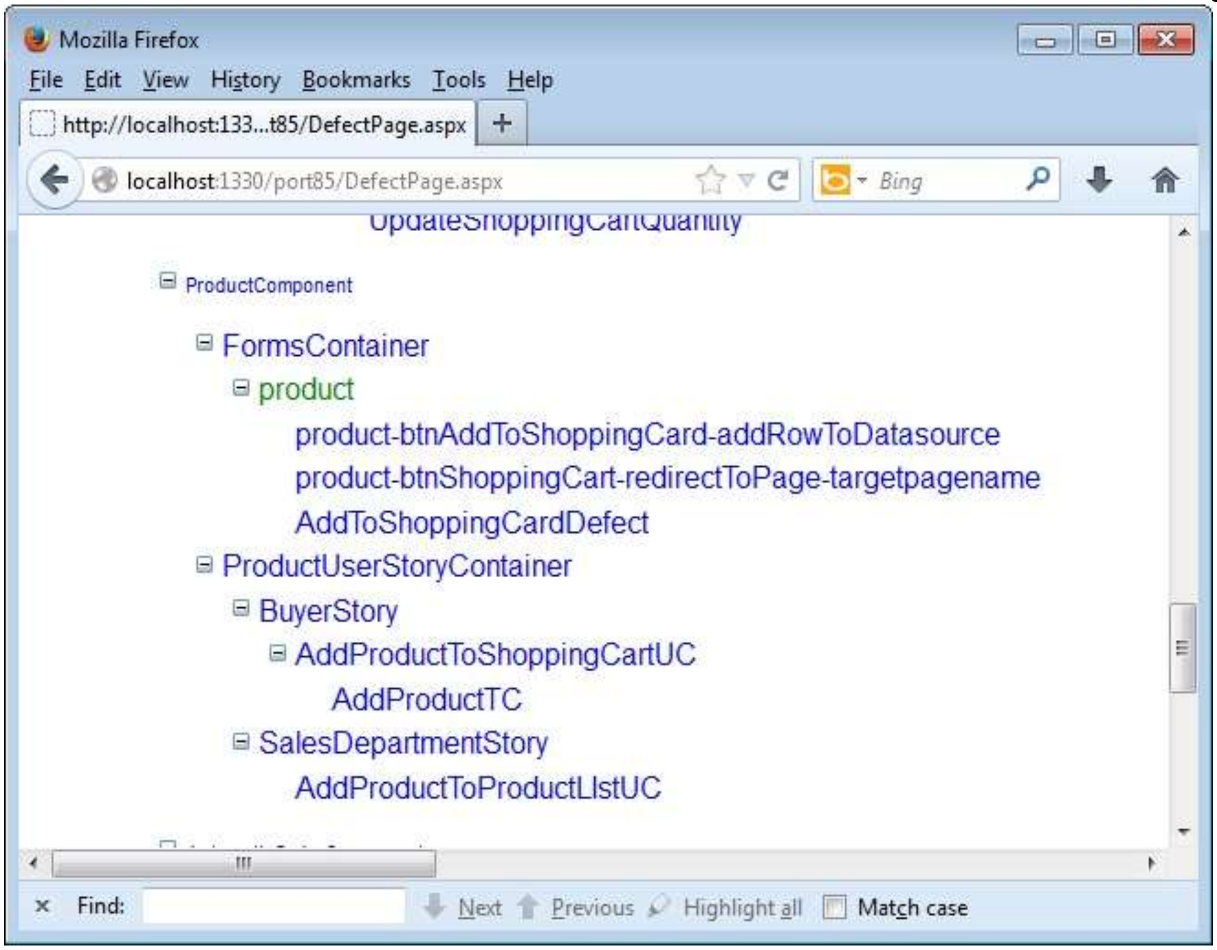
On the left side of the screen is the navigation tree that shows all the generated objects. On the right is the last generated forms display. The Framework's job is accomplished when the source code and executables are generated. The Framework has nothing more to do with validation and code execution. Responsible for the code testing and validation are the customers and requirement negotiation team. The code is adapted to be executed inside of a Microsoft Visual Studio environment and future testing and validations are executed in a development and test environment.

Generated forms are fully functional applications. On the top of the product forms are previous ("<") and next (">") navigation buttons, as well as "Save" and "Delete" buttons. The insert and update row functions are attached to the "Save" button. If a row already exists it will be updated, otherwise a new row will be inserted. This task belongs to the standard functionality that is assigned to each form and is created by the Framework.

Methods from the GenericMethodClass are assigned to the “Add to ShoppingCart” and “Shopping Cart” buttons, as described in the Figure 28. The “redirectToPage” method assigned to “Shopping Cart” button is a generic method that can be used to test application workflow.

In Figure 33 is evidence of a cosmetic defect. The “Add to Shopping Card” button title should be renamed to “Add to Shopping Cart” title. A Defect can be added to the design and to the place where defect occurs, the product forms.

The Figure 34 shows AddToShoppingCardDefect in the FormsContainer and product form design:

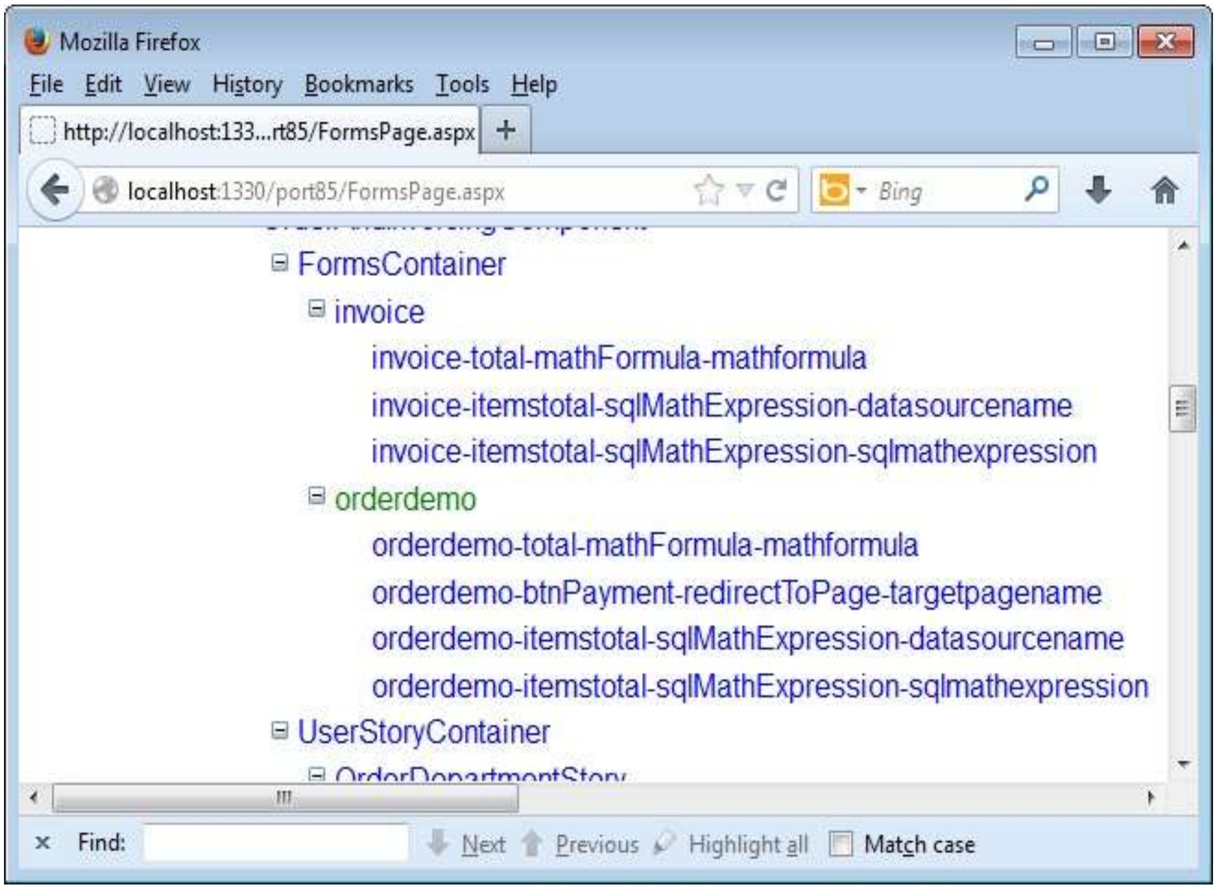

Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:133...t85/DefectPage.aspx
localhost:1330/port85/DefectPage.aspx
Bing
Find:
Next Previous Highlight all Match case

UpdateShoppingCartQuantity
ProductComponent
FormsContainer
product
product-btnAddToShoppingCard-addRowToDatasource
product-btnShoppingCart-redirectToPage-targetpagename
AddToShoppingCardDefect
ProductUserStoryContainer
BuyerStory
AddProductToShoppingCartUC
AddProductTC
SalesDepartmentStory
AddProductToProductLIstUC

Figure 34 Product Forms Defect

In Figure 34, the AddToShoppingCardDefect is assigned to the product form. The product form has two action buttons designed, and to the btnAddToShoppingCard field is assigned a addRowToDatasource application object method and to the btnShoppingCart is assigned a redirectToPage application object method.

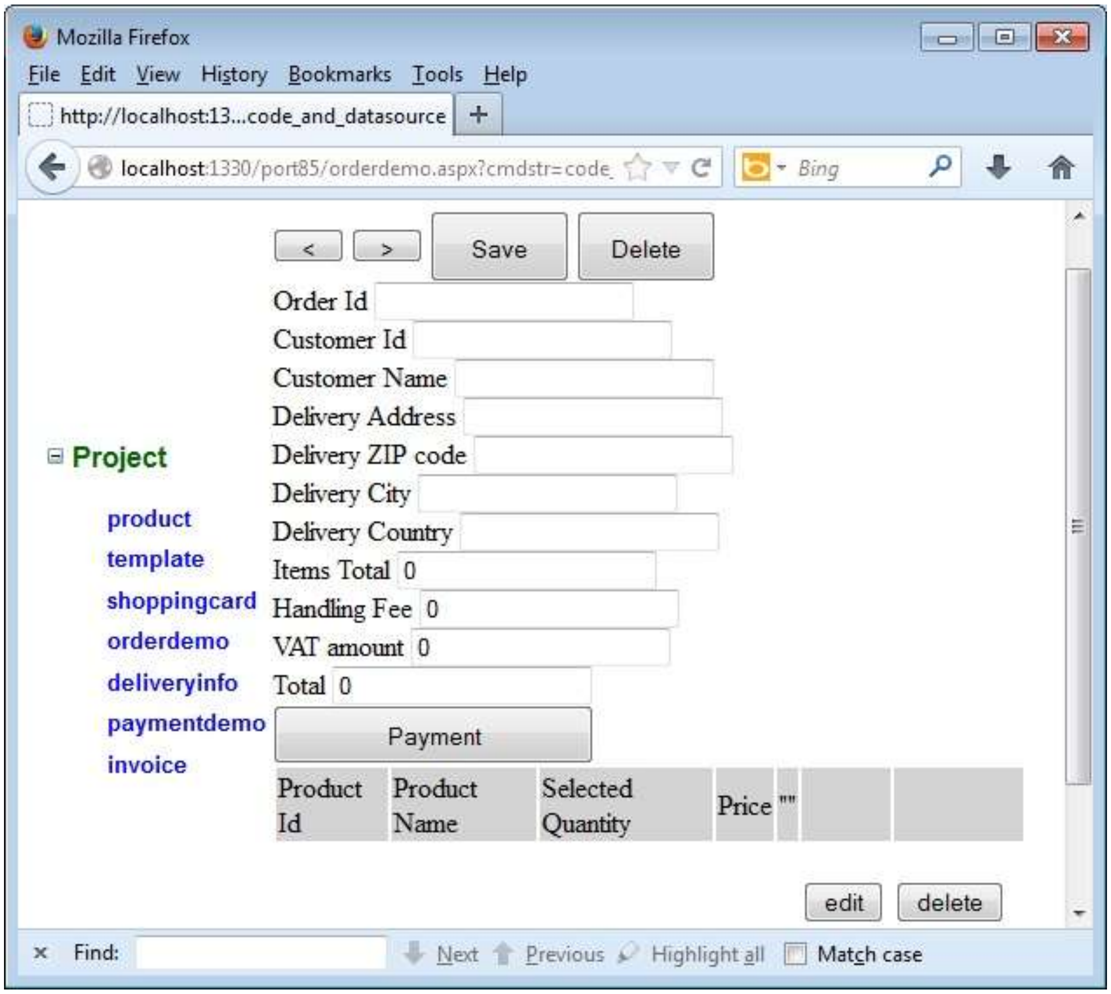
The Generator generates each designed object according to the definitions that are stored in the permanent storage, and creates a fully functional application that is able to receive user inputs and store inputs in the permanent storage, and process data according to the design requirements. Figure 35 illustrates more actions that are assigned to the orderdemo form fields:


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:133...rt85/FormsPage.aspx
localhost:1330/port85/FormsPage.aspx
Bing
Find: Next Previous Highlight all Match case

FormsContainer
invoice
invoice-total-mathFormula-mathformula
invoice-itemstotal-sqlMathExpression-datasourcename
invoice-itemstotal-sqlMathExpression-sqlmathexpression
orderdemo
orderdemo-total-mathFormula-mathformula
orderdemo-btnPayment-redirectToPage-targetpagename
orderdemo-itemstotal-sqlMathExpression-datasourcename
orderdemo-itemstotal-sqlMathExpression-sqlmathexpression
UserStoryContainer

Figure 35 Orderdemo Designed Actions

The tree view shows each of designed actions and forms fields where action is assigned. When a form is generated, the Framework redirects to the form Web page. Figure 36 illustrates the orderdemo Web page:



Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://localhost:13...code_and_datasource

localhost:1330/port85/orderdemo.aspx?cmdstr=code_

< > Save Delete

Project

- product
- template
- shoppingcard
- orderdemo
- deliveryinfo
- paymentdemo
- invoice

Order Id	
Customer Id	
Customer Name	
Delivery Address	
Delivery ZIP code	
Delivery City	
Delivery Country	
Items Total	0
Handling Fee	0
VAT amount	0
Total	0

Payment

Product Id	Product Name	Selected Quantity	Price	""		

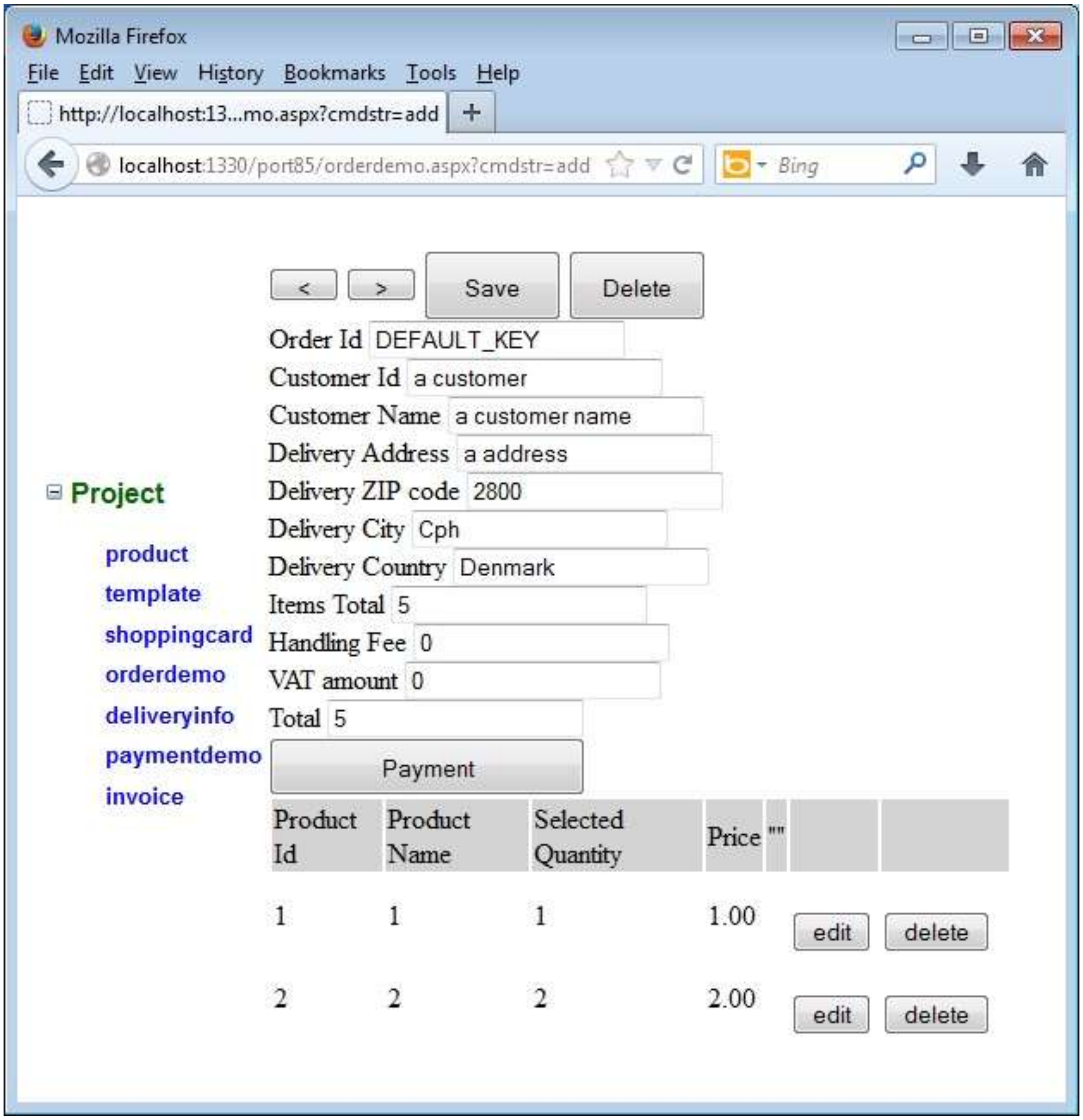
edit delete

Find: Next Previous Highlight all Match case

Figure 36 Orderdemo Forms Generated

The orderdemo form is interesting because to this form are assigned math functions that calculate the Items Total amount and order Total amount, based on the number of product items, item price, VAT amount, and handling fee amount. In Figure 36 the orderdemo form design details are displayed.

The orderdemo form test is described in Chapter 16.2.8 “Calculate Order Items Total” Use Case, in Chapter 16.2.9 “Calculate Order Total With Handling Fee” Use Case, and in Chapter 16.2.10 “Calculate Order Total With VAT” Use Case. Figure 37 shows the expected results according to the test described in Chapter 16.2.8 “Calculate Order Items Total” Use Case:


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:13...mo.aspx?cmdstr=add
localhost:1330/port85/orderdemo.aspx?cmdstr=add
Bing
<
>
Save
Delete
Project
product
template
shoppingcard
orderdemo
deliveryinfo
paymentdemo
invoice
Payment

Order Id	DEFAULT_KEY
Customer Id	a customer
Customer Name	a customer name
Delivery Address	a address
Delivery ZIP code	2800
Delivery City	Cph
Delivery Country	Denmark
Items Total	5
Handling Fee	0
VAT amount	0
Total	5

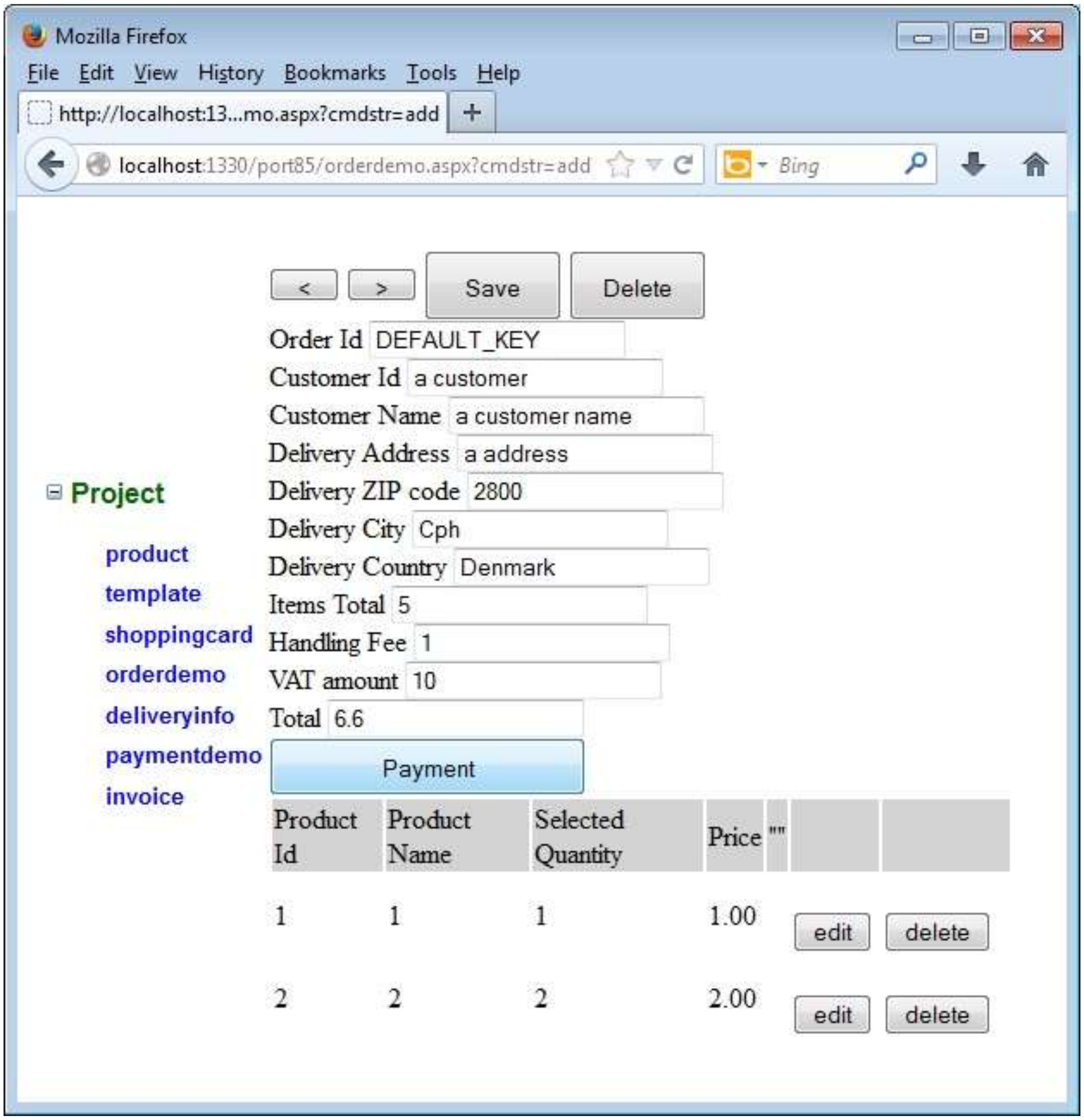
Product Id	Product Name	Selected Quantity	Price	""		
1	1	1	1.00		edit	delete
2	2	2	2.00		edit	delete

Figure 37 Orderdemo Form Initial Test

The Items Total initial value is set to 5. This means that the generic methods attached to the Items Total have been fired and calculated the Selected Quantity * Price for each order item.

The Total is set to 5 and is correct because the Handling Fee and VAT amount are set to 0, but this test cannot confirm that the Total calculation is working as expected. To be sure that this calculation is triggered and is working as expected, it is necessary to change these two values.

Figure 38 shows the expected results according to the test described in Chapter 16.2.10 "Calculate Order Total With VAT" Use Case:


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:13...mo.aspx?cmdstr=add
localhost:1330/port85/orderdemo.aspx?cmdstr=add
Bing
< > Save Delete
Project
product
template
shoppingcard
orderdemo
deliveryinfo
paymentdemo
invoice
Payment
edit delete

Order Id	DEFAULT_KEY
Customer Id	a customer
Customer Name	a customer name
Delivery Address	a address
Delivery ZIP code	2800
Delivery City	Cph
Delivery Country	Denmark
Items Total	5
Handling Fee	1
VAT amount	10
Total	6.6

Product Id	Product Name	Selected Quantity	Price	""		
1	1	1	1.00		edit	delete
2	2	2	2.00		edit	delete

Figure 38 Orderdemo Form Handlingfee and Vat amount Changed Test

The Items' Total amount is correct and is not changed. The Total amount is changed and is correct according to the designed calculation "5 + (5 + 1) * 10 /100 = 6.6".

This test confirms that calculations are triggered and executed according to the design information created by the GRA Framework, and confirms that the designed operands are used correctly in the calculations.

16 Appendix D – Retail Store Test Documentation

"Beware of bugs in the ~~above~~ code; I have only proved it correct, not tried it." (Donald Knuth)

This chapter is dedicated to the validation of the generated source code and testing of the Retail Store application. The development effort in this dissertation has been focused on proving that the functional requirements are working, and in this implementation of the GRA Framework only the errors that prevent application execution or the appearance of incorrect operation results are corrected. The Use Cases used for the Retail Store application testing, where the primary focus is on the successful scenario workflow and where alternative scenarios are ignored, reflects this intention.

For the implementation of the GRA, only the available technical platform features are used to reduce the amount of work necessary to develop code for employing that which can be reused. Such features are implementation-specific and different technical platforms would require different solutions. In this dissertation the following technical platform is used:

- Microsoft Windows 7 Professional Operating System (OS)
- Microsoft .NET Framework version 4.5.50709
- Microsoft ASP.NET version 2012.3.41009
- Microsoft Visual Studio Express 2012 for Web
- Microsoft C# language
- Oracle MySQL database version 5.6.10.1
- Oracle MySQL Connector NET version 6.6.5

In this software list only Microsoft Windows 7 Professional Operating System (OS) requires a payable license. The other software that belongs to the technical platform can be downloaded free of charge from the Microsoft and Oracle Web sites. Each product contains a detailed installation guide.

Although the presented solution is sufficient for demonstrating method implementation and the generation of source code, this is not yet a software product and this implementation solely has academic and research purposes.

16.1 Generated Source Code Validation

The generated source code is validated by a:

- Compiler
- Runtime environment

Using the compiler and runtime environment for generated code validation fits well to the GRA's basic philosophy to use already available technical platform features to reduce the amount of the work necessary for developing code to implement that which can be reused.

The workflow diagram in Figure 39 describes source code validation process:

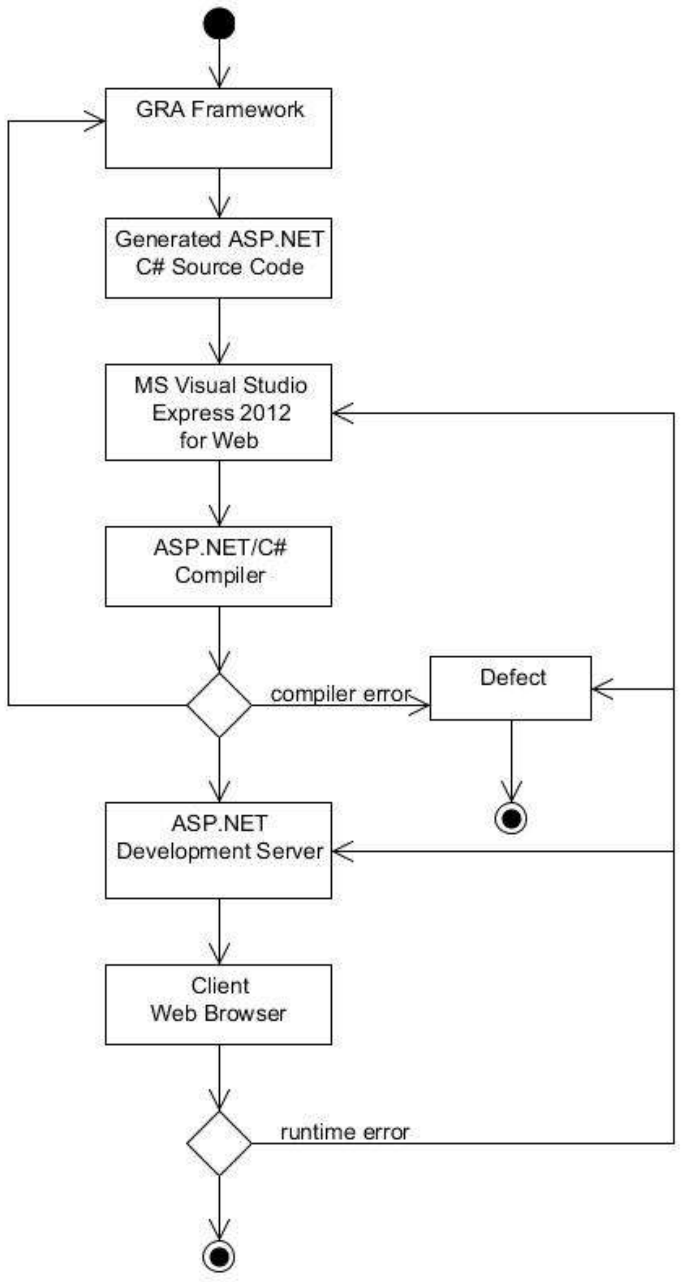

GRA Framework
Generated ASP.NET C# Source Code
MS Visual Studio Express 2012 for Web
ASP.NET/C# Compiler
compiler error
Defect
ASP.NET Development Server
Client Web Browser
runtime error

Figure 39 Generated Source Code Validation

The source code generated by the GRA Framework is immediately available for the MS Visual Studio Express 2012 for the Web, and the GRA Framework tries to execute the generated source code. Before the generated code can be executed, the MS Visual Studio needs to compile it. The ASP.NET/C# compiler will check syntax and semantics, parsing and preprocessing, and report any kind of compiler errors. If there is a compiler error, such as an undefined variable or reference to an undeclared class or method, the user may be able to correct it by changing the descriptions in the GRA Framework; otherwise, the error needs to be reported as a Defect. A compiler error can be related to the wrong MS Visual Studio version or a missing installation of the correct Microsoft .NET framework. Such kinds of errors should be corrected by the installation of the software versions required by technical platform described in Chapter 16 “Appendix D – Retail Store Test Documentation”.

If compilation is accomplished successfully, then the ASP.NET Development Server—the Web server delivered as a part of the MS Visual Studio installation package—executes a generated source code. The Client's access to the application code is achieved using a Web browser. When the code is executed, a runtime error can occur. The runtime errors are usually related to an improper technical platform software installation or to the corrupted database files or configuration files. The runtime error example can be missing the connection to the MySQL database, which can be caused by a missing or incorrect installation of Oracle MySQL Connector NET version 6.6.5. If the runtime error cannot be corrected then it is reported as a Defect. The Defect reporting’s primary purpose is to keep track of issues that need to be implemented in the next version.

16.2 Retail Store Functional Testing

The Use Cases presented in this chapter are used to test the Retail Store application. The Use Cases are based on the following User Stories described in Chapter 7 “GRA Framework Validation”:

- The RetailStoreProject
- The BuyerStory
- The SalesDepartmentStory

While the RetailStoreProject User Story describes requirements related to the application architecture, the Retail Store functional requirements are described in the BuyerStory User Story and SalesDepartmentStory. Figure 6 describes the Retail Store application workflow.

The test of the implementation has been focused on proving that the functional requirements are working and in this implementation of the GRA Framework, only errors that prevent application execution or a display of incorrect operation results are corrected. The Use Cases used for the Retail Store application testing—where the primary focus is on the success of the scenario workflow and alternative scenarios are ignored—reflects this intention.

16.2.1 Save Button Add Record

Name	Save Button Add Record
Scope	Web Interface, Back-end, database
Primary Actor	User
Precondition	Internet connection, Web Browser is running, connection to URL http://www.port85.com//test/eCommerceSite/product.aspx?cmdstr=null Record Product ID = 1 and Product ID = 2 do not exist
Post-condition	
Brief Description	Save Button adds new record to the database table
Main Scenario	1. Enter URL address in the Web Browser address field and press ENTER 2. Browser displays: Projectt > eCommerceSite.product form. 3. Enter : Product ID = 1, Name = 1, Description = 1, Price = 1, Quantity = 1, Selected Quantity = 1 4. Click Save button. 5. Browser resets all fields described in step 3 6. Enter: Product ID = 2, Name = 2, Description = 2, Price = 2, Quantity = 2, Selected Quantity = 2 7. Click Save button. 8. Click on the “>” button 9. Browser displays record Product ID = 1 10. Click on the “>” button 11. Browser displays record Product ID = 2
Alternate Scenario	
Business Rules	• If the record Product ID exists, the fields described in the step 3 will not be reset • If the record Product ID exists and any field’s value is changed, after clicking on Save button the record will be updated with the

	changed field value
Special Requirements	
Parent Use Case	
Child Use Case	
Reference	SalesDepartmentStory User Story, described in the Chapter 7 “GRA Framework Validation”
Success criteria	The currently entered record is added to the database table.

16.2.2 Save Button Update Record

Name	Save Button Update Record
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Save Button Add Record** Use Case successfully executed Record Product ID = 2 does exist The currently displayed record is record where Product ID = 2
Post condition	
Brief Description	Save Button updates currently selected record
Main Scenario	Continue after step 12 Main Scenario in **Save Button Add Record** Use Case. 1. Enter : Quantity = 5 2. Click Save button. 3. Click on the “>” button until you get Product ID = 2 4. Browser displays record where Product ID is 2 and Quantity = 5
Alternate Scenario	
Business Rules	• If the record Product ID exists and any field’s value is changed, after clicking on Save button the record will be

	updated with the changed field value
Special Requirements	
Parent Use Case	**Save Button Add Record**
Child Use Case	
Reference	SalesDepartmentStory User Story, described in Chapter 7 "GRA Framework Validation"
Success criteria	The currently changed record is updated in the database table.

16.2.3 Delete Button

Name	Delete Button
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Save Button Add Record** Use Case successfully executed The currently displayed record is record where Product ID = 2
Post-condition	
Brief Description	Delete Button deletes currently selected record
Main Scenario	Continue after step 12 Main Scenario in **Save Button Add Record** Use Case. 1. Click on the "Delete" button 2. All fields are set to empty values 3. Click on the ">" button and verify that record Product ID = 2 does not exist 4. The current record is Product ID = 1 5. Click on the "Delete" button 6. Click on the ">" button and verify that record Product ID = 1 does not exist
Alternate Scenario	
Business Rules	
Special	

Requirements	
Parent Use Case	**Save Button Add Record**
Child Use Case	
Reference	SalesDepartmentStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	The currently selected record is deleted from the database table.

16.2.4 Browse Buttons

Name	Browse Buttons
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Save Button Add Record** Use Case successfully executed The currently displayed record is record where Product ID = 2
Post-condition	
Brief Description	Delete Button deletes existing record
Main Scenario	Continue after step 12 Main Scenario in **Save Button Add Record** Use Case. 1. Click on the “<” button 2. Verify that currently selected record changes to Product ID = 1 3. Click on the “>” button 4. Verify that currently selected record changes to Product ID = 2
Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**Save Button Add Record**
Child Use Case	

Reference	SalesDepartmentStory User Story and BuyerStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	Browse through list of the available records.

16.2.5 Add To Shopping Cart Button

Name	Add to Shopping Cart Button
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Browse Buttons** Use Case successfully executed The currently displayed record is record where Product ID = 2
Post-condition	
Brief Description	Add to Shopping Cart Button adds selected record to the shopping cart list
Main Scenario	Continue after step 4 Main Scenario in **Browse Buttons** Use Case. 1. Click on the “Add to Shopping Cart” button 2. Click on the “<” button 3. Verify that currently selected record is changed to Product ID = 1 4. Click on the “Add to Shopping Cart” button 5. Click on the “eCommerceSite.shoppingcart “link in the navigation bar on the left side of the screen 6. Verify that currently displayed form is Project > eCommerceSite.shoppingcart form 7. Click on the “>” button 8. Verify that currently displayed record is Product ID = 1 9. Click on the “>” button 10. Verify that currently displayed record is Product ID = 2
Alternate Scenario	

Business Rules	
Special Requirements	
Parent Use Case	**<u>Browse Buttons</u>**
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	The shoppingcart list contains Product ID = 1 and Product ID = 2 records.

16.2.6 Create Order

Name	Create Order
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**<u>Add to Shopping Cart Button</u>** Use Case successfully executed
Post-condition	
Brief Description	Create Order creates order items from the shoppingcart list
Main Scenario	Continue after step 10 Main Scenario in **<u>Add to Shopping Cart Button</u>** Use Case. 1. Click on the “Add to Order” button 2. Click on the “<” button 3. Verify that currently selected record is changed to Product ID = 1 4. Click on the “Add to Order” button 5. Click on the “eCommerceSite.orderdemo” link in the navigation bar on the left side of the screen 6. Verify that currently displayed form is <u>Project</u> > eCommerceSite.orderdemo form 7. Verify that in the order items list are Product ID = 1 and Product ID = 2 items

Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**Add to Shopping Cart Button**
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	The selected shoppingcart list records are added to the list of order items.

16.2.7 Delivery Info

Name	Delivery Info
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Create Order** Use Case successfully executed
Post-condition	
Brief Description	Delivery Info adds delivery information to the order items from the shoppingcart list
Main Scenario	1. Click on the “eCommerceSite.deliveryinfo” link in the navigation bar on the left side of the screen 2. Enter: Customer Id = testcustomer, Customer Name = TEST_CUSTOMER, Delivery Address = Kongens Lyngby 48, ZIP code = 2800, Delivery City = Copenhagen, Delivery Country = Denmark 3. Click on the “Update Order” button 4. Click on the “eCommerceSite.orderdemo” link in the navigation bar on the left side of the screen 5. Verify that the currently displayed form is Project > eCommerceSite.orderdemo form 6. Click on the “>” button 7. Verify that Customer Id = testcustomer, Customer

	Name = TEST_CUSTOMER, Delivery Address = Kongens Lyngby 48, ZIP code = 2800, Delivery City = Copenhagen, Delivery Country = Denmark
Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**Create Order**
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	Delivery information is added to the orderdemo.

16.2.8 Calculate Order Items Total

Name	Calculate Order Items Total
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Delivery Info** Use Case successfully executed
Post-condition	
Brief Description	Calculate order Items Total according to the following formula: Items Total = (Selected Quantity 1 * Price 1) + (Selected Quantity 2 * Price 2) + (Selected Quantity n * Price n)
Main Scenario	Continue after step 7 Main Scenario in **Delivery Info** Use Case. 1. Click on the “<” button 2. Verify that Items Total = 5 3. Click on the “Update Order” button 4. Click on the “eCommerceSite.orderdemo” link in the navigation bar on the left side of the screen 5. Verify that currently displayed form is Project >

	eCommerceSite.orderdemo form 6. Click on the “>” button 7. Verify that Customer Id = testcustomer, Customer Name = TEST_CUSTOMER, Delivery Address = Kongens Lyngby 48, ZIP code = 2800, Delivery City = Copenhagen, Delivery Country = Denmark
Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**<u>Delivery Info</u>**
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 “GRA Framework Validation”
Success criteria	Order Items Total = 5, which is calculated from the two order items, products 1 and 2, according to the formula (1 * 1) + (2 * 2) = 1 + 4 = 5

16.2.9 Calculate Order Total With Handling Fee

Name	Calculate Order Total With Handling Fee
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**<u>Calculate Order Items Total</u>** Use Case successfully executed
Post-condition	
Brief Description	Calculate order Total according to the following formula: Items Total = itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100
Main Scenario	1. Enter: Handling Fee = 1 and press ENTER key 2. Verify that Total = 6

Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**Calculate Order Items Total**
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 "GRA Framework Validation"
Success criteria	Order Total = 6 what is calculated from the two order items, and handling fee Total = 5 + 1 + (5 + 1) * 0/100 = 5 + 1 + 0 = 6

16.2.10 Calculate Order Total With VAT

Name	Calculate Order Total With VAT
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	**Calculate Order Total With Handling Fee** Use Case successfully executed
Post-condition	
Brief Description	Calculate order Total according to the following formula: Items Total = itemstotal + handlingfee + (itemstotal + handlingfee) * vatamount / 100
Main Scenario	1. Enter: VAT amount = 10 and press ENTER key 2. Verify that Total = 6.6
Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	**Calculate Order Total With Handling Fee**

Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 "GRA Framework Validation"
Success criteria	Order Total = 6.6, which is calculated from the two order items, and handling fee Total = 5 + 1 + (5 + 1) * 10/100 = 5 + 1 + 0.6 = 6.6

16.2.11 Credit Card Payment

Name	Credit Card Payment
Scope	Web Interface, Back-end, Database
Primary Actor	User
Precondition	
Post-condition	
Brief Description	Layout for entering credit card information for online payment
Main Scenario	1. Click on the "eCommerceSite.paymentdemo" link in the navigation bar on the left side of the screen 2. Enter: Payment Id = 1, Credit Card Name = VISA, Credit Card Number = 1234567890123456, Expiration Month = 1, Expiration Year = 19, Code Number = 123 3. Click on the "Confirm Payment" button 4. Verify that all form fields are empty
Alternate Scenario	
Business Rules	
Special Requirements	
Parent Use Case	
Child Use Case	
Reference	BuyerStory User Story, described in Chapter 7 "GRA Framework Validation"
Success criteria	It is possible to enter credit card information.