

A Demonstrator Framework for Consistency Management Approaches

by

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A Demonstrator Framework for Consistency Management Approaches

Master's Thesis

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by

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Declaration

I hereby declare that I prepared this thesis entirely on my own and have not used outside sources without declaration in the text. Any concepts or quotations applicable to these sources are clearly attributed to them. This thesis has not been submitted in the same or substantially similar version, not even in part, to any other authority for grading and has not been published elsewhere.

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1 Introduction

Bidirectional transformation (denoted by "bx") is a technique used to synchronize two (or more) instance of different meta-models. Both models are related, but don't necessarily contain the same information. Changes in one model thus lead to changes in the other model [1]. Bx makes sure that two models that can change over time have to be kept constantly consistent with each other.

Bidirectional transformation is used to deal with scenarios like:

- change propagation to the user interface as a result of underlying data changes
- synchronization of business/software models
- refreshable data-cache incase of database changes
- consistency management between two artifacts by avoiding data loss

and many more....

1.1 Contribution

Bx community has been doing research and development work in many fields like software development, database, mathematics and much more to increase awareness and to reach more people [2][1]. As a result, many kinds of bx tools are being developed, e.g., eMoflon [7], Echo [10]. These bx tools are based on various approaches, such as graph transformations, bidirectionalization, update propagations [8] and can be used in different areas of application.

1.2 Problem Statement

Bidirectional transformation is an emerging concept. In the past, many efforts have been made by conducting international workshops, seminars and through experiments conducted by developers / bx community to identify its potential. Also, in addition to the development of bx tools and bx language, benchmarks are being created for bx tools for systematic comparison [4].

Although a significant amount of work has been done in this field, some basic problems still remain:

- Reachability to relevant communities is not significant due to the absence of a common vocabulary for bx across research disciplines [3]. Seminars are still conducted for exchanging ideas in different communities to define a common vocabulary of terms and properties for bx [2].

- Bx tools and their applicability is still not widely known even in the developers' communities. Due to the existing conceptual and practical challenges associated with using bx, bx-tools in building software systems, many developers and researchers are still using non-bx transformation tools to achieve properties which can be easily supported by bx-tools [3].
- Absence of a simple yet interactive bx tool demonstrator to depict the potential of *bidirectional transformation* over preferred non-bx tool demonstrators among developers' and researchers' communities [3].

1.3 Solution Strategy

To solve the problems as described in Section 1.2, in this thesis, my goals are as follows:

- Design and implement an interactive demonstrator.
- Spreading the basic concepts of bx to a wide audience and making them accessible and understandable.

An existing bx tool will be used as a part of the demonstrator to realize *bidirectional transformation*. The final prototype will be interactive and easily accessible to users to help them understand the potential, power and limitations of bx.

1.4 Structure

This document is structured as follows:

Chapter 1 (introduction) contains the introduction about the thesis topic and motivation behind the making of this thesis with a solution strategy.

Chapter 2 describes the related work that has been done on bx in last few years and the related problems.

Chapter 3 explains the research questions that I aimed at solving throughout my thesis, research method and implementation idea.

Chapter 4 describes the architecture(application framework) design in brief with related diagrams.

Chapter 5 provides the layer-wise implementation details of the application along with an application overview.

Chapter 6 contains the feedback from user groups, evaluation results and learning goals(based on research questions).

Last chapter summarizes all the work which was done as part of this thesis and draws useful conclusions followed by future work.

2 Foundation

In this chapter I will describe some commonly used terms with respect to bx

3 Related Work

Model transformation is a central part of Model-Driven Software Development [1] [2]. The main concept of synchronization is to propagate changes from some model to other related models.

Bx community has been constantly doing research and development work in many fields to help people understand and increase awareness about bx. Nowadays, researchers from different areas are actively investigating the use of bx to solve a variety of problems. A lot of work has been done in terms of building usable tools and languages for bx. These tools can be used in various fields, for achieving *bidirectional transformation*. To understand these tools, several handbooks, tutorials and examples have been created so that users and developers can understand the core concepts.

3.1 Handbooks & Tutorials

As a part of our research, we have analyzed some tutorials and tools and below are our findings.

Anjorin et al.[7] present the concept for *bidirectional transformation* using Triple Graph Grammars (denoted by "TGG") [5]. To demonstrate their core idea and the usage of the tool, they have described an example by transforming one model (source) into another (target) through TGG transformations [5][6]. The whole tutorial is about 42 pages long which guides the user to get the example running through a series of steps. These steps include installing Eclipse¹, getting their tool as an Eclipse plugin, setting up the workspace, creating TGG schema and specifying its rule and much more. If the user is able to execute each step correctly, then finally he/she can view the final output. It took me 4 days to get the tool up and running.

We have analyzed a tutorial[12] on a bidirectional programming language BiGUL[11]. The core idea with BiGUL is to write only one putback transformation, from which the unique corresponding forward transformation is derived for free. The whole tutorial is about 45 pages long which includes a lot of complex formulas, algorithms and guides the user to get the example running through a series of steps. These steps include installing BiGUL, setting up the environment, achieving bx through BiGUL's bidirectional programming and much more. If the user is able to execute each step correctly, then finally he/she can view the final output.

¹Integrated Development Environment (IDE) for programming Java

3.2 Example Repositories

A rich set of bx examples repository [9] has been created based on many research papers. These examples cover a diverse set of areas such as business process management, software modelling, data structures, database, mathematics and much more.

User can find relevant information about the examples on the respective web pages. Some of the examples are very well documented along with class diagrams, activity diagrams, object diagrams etc. and source code of a few examples are available as well.

3.3 Existing Demonstrators

Also, we have analyzed an existing demonstrator available along with the test cases of a domain-specific language, BiYacc [13] which is based on BiGUL [11].

Being an online demonstrator, a user can try it out instantly and check how it works. It doesn't require any installation or technical expertise to get the example running and also, it makes the features of bx noticeable.

3.4 Virtual Machines

Also, we have analyzed a web-based virtual machine, e.g., SHARE [14]. Basically, this is a web portal used for creating and sharing executable research papers and acts as a demonstrator to provide access to tools, softwares, operating systems, etc., which are otherwise a headache to install [14].

This provides the environment that the user requires to execute his/her tool or program. Hence, it reduces the overhead of a user for maintaining and organizing all software framework related stuff and simplify access for end-users.

3.5 Related Problems

Some associated problems that I found with the above paragraphs are as follows:

- Installation requires technical expertise and time consuming as the user typically has to setup and install the tool.
- Steps to get the example running needed technical expertise, e.g., In some cases domain specific knowledge includes mathematics and specific coding language. What is show-

3.5 Related Problems

cased and discussed is tied to a specific technological space and might not be easily transferable to other bx approaches.

- Not very helpful to understand what bx is before deciding which bx tool (and corresponding technological space) to use.
- The existing demonstrator's visual representation doesn't create interest in the target audience as it does not exploit the potential of using an interactive GUI and colors, etc. It just makes use of two text fields and is comparable to a console-based interface that is accessible online.
- The demonstrator is based on a rather technical example that might not be relevant, interesting, or convincing for a large group of potential bx users.
- For security reasons, it's not like other web portals where a user need to simply sign-up and can host/create/access data, rather it includes a series of request-grant cycle for getting access to an environment and hosting/managing data. Also, some actions require special authorization and take time to complete the whole process.

4 Requirements

4.1 Objectives

The goal of this thesis is to explore the fundamental and technical challenges involved in implementing a demonstrator for bx tools.

This thesis aims at answering these main research questions:

RQ1 – What are the core requirements for implementing a successful bx demonstrator ?

RQ2 – What kind of interactivity and to what extent is it required in the bx demonstrator ?

RQ3 – Which goals can be particularly well addressed in a bx demonstrator and why ?

RQ4 – To what extent is such a bx demonstrator reusable?

RQ4 can be split into the following sub-questions:

RQ4.1 – Is the implementation of the demonstrator bx tool-specific ?

RQ4.2 – Is the implementation of the demonstrator example-specific?

RQ4.3 – What part(s) of the demonstrator can be reused in implementing a different example ?

All of my work is directly or indirectly related to the above research questions.

4.2 Learning Goals

Along with exploring the challenges as described in Section 4.1, I am also focussing on teaching some basic concepts to the user about bx in the process of trying/playing with the demonstrator.

What am I trying to teach?

- Bidirectional is not always bijective.
- Not all changes can be propagated. In this case, consistency needs to be preserved.
- In BX, Challenge is to avoid or minimise information loss.
- Current limitation - you can only change one side.
- Synchronisation is interactive (to handle non-determinism).

4.3 End Result

As my thesis is more focussed on the implementation of a demonstrator for consistency management based on a bx tool, following are the end results I am trying to achieve:

- Reduce the installation time of the bx tool by making the demonstrator available online. Hence, the user is just a click away to try the bx tool and needs nothing to install on his/her machine.
- Demonstrator should be interactive and fun to play with.
- User should be able to learn/understand the concepts of bx as described in Section 4.2.

4.4 Implementation Phases

My work is based on an evolutionary case study² which focuses on designing and implementing a successful bx tool demonstrator. My entire work cycle is described in the following paragraphs.

Case Study

Examples and Implementation

Evaluation

²Case Study which keeps on evolving with time

5 High-Level Concepts

5.1 Implementation Idea

Due to the existing pain points with the bx tools, as described in Section ?? and to solve the problems as described in Section 3.5, the main idea is to design and implement an interactive bx tool demonstrator.

5.1.1 Choosing an Example

We have discussed a few examples for implementation as follows:

Task Management This prototype can be used for allocating tasks in a team. It contains two views e.g., supervisor's view and employee's view. A Supervisor can allocate tasks to their subordinates. An employee can view the tasks assigned to him. Then the task will go through a life cycle as the work progresses, i.e., Assigned, In Progress, Testing, Done. Supervisor's view shows aggregate information from multiple projects and multiple employees, but does not contain detailed information, e.g., tasks have fewer states than for assigned employees. Bx rules control how updates are handled and states are reflected in the different views of the project, e.g., the employee's view will be updated for each state change, whereas the supervisor's view is only updated when a task is completed and not for intermediate changes.

Quiz This prototype can be used for an online quiz game. It contains two views e.g., administrator's view and participant's view. There will be a large set of questions related to different areas, e.g, history, geography, politics, sports, etc. The administrator can select the areas from which the questions will be shown to the participant and initiate the game. The participant can override the selection of the areas and start the quiz. Randomly questions will be shown to the participant from the selected areas with 4 options. The administrator's view contains less information than the participant's view, e.g., only the result of each question will be shown to the administrator, whereas participant can see questions along with its options. As soon as the participant chooses the answer to any question, bx rules control how updates are handled and states are reflected in the different views of the project.

Playing with Shapes It contains two views e.g., low-level view (depicts UI³ for low-level language, i.e., UI with less functionality) and high-level view (depicts UI for high-level language, i.e., UI with more functionality). User will draw a geometric shape, i.e., triangle

³short for User Interface

5.2 BX Tool Selection

/ square / rectangle / circle with some notations similar to the shape on the low-level view and if the notations are correct, the high-level view tries to recognize the shape and draws it with default parameters and vice-versa. Basically the transformation will happen between a low-level language and a high-level language and bx rules control how updates are handled and states are reflected in the different views of the project. In high-level view, more functionalities will be present, i.e., moving one shape from one place to another, creating a clone of an existing shape, etc. which is not possible in low-level view.

Arranging a Kitchen It contains two views e.g., low-level view (depicts a grid structure containing blocks) and high-level view (empty space which depicts UI for kitchen). High-level view has more functionalities such as creating/ deleting/ moving an kitchen item, etc. out of which only a few will be available in low-level view. User will create/ delete/ move a kitchen item, i.e., sink / table on the high-level view and if changes done on the high-level view are according to the rules defined in the bx tool then items will be reflected on the low-level view with same colored blocks and vice-versa. Basically the transformation will happen between a low-level language and a high-level language and bx rules control how updates are handled and states are reflected in the different views of the project.

5.2 BX Tool Selection

5.3 Concrete Design Decision and High-Level Architecture Information

High-Level Architecture diagram of my prototype is given in Figure 1.

5.3.1 View (GUI)

5.3.2 Controller

5.3.3 Model

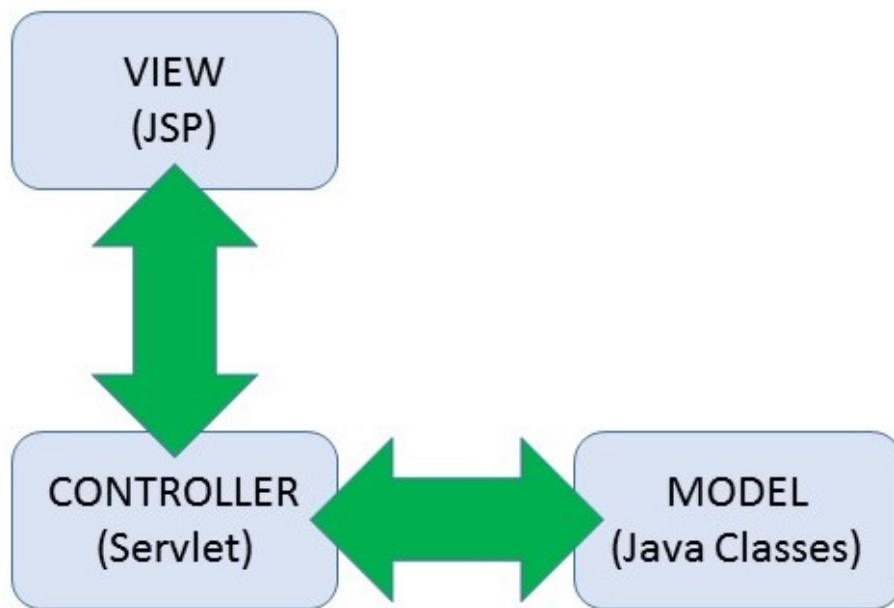


Figure 1: High Level Architecture Diagram

6 Low-Level Concepts

6.1 UML Diagrams

6.1.1 Component Diagram

Component diagram of my prototype is given in Figure 2.

I am using Model-View-Controller (MVC) pattern for my application framework. On the top, `View` (Web Browser) component is present which contains a graphical user interface and functionalities that belong to the user. With the changes on `View` component, data are being provided through interface `IDoAnalysis` to the `Controller` component and after the calculations are done, the results are sent back to the `View` through interface `IProvideResults`. Both `View` and `Controller` resides on the same machine. `Model` (`Bx Tool`) component encapsulates and manages the state of all models by communication with the `Controller` through interface `IRules`.

6.1.2 Class Diagram

6.1.3 Sequence Diagram

6.2 Core Details

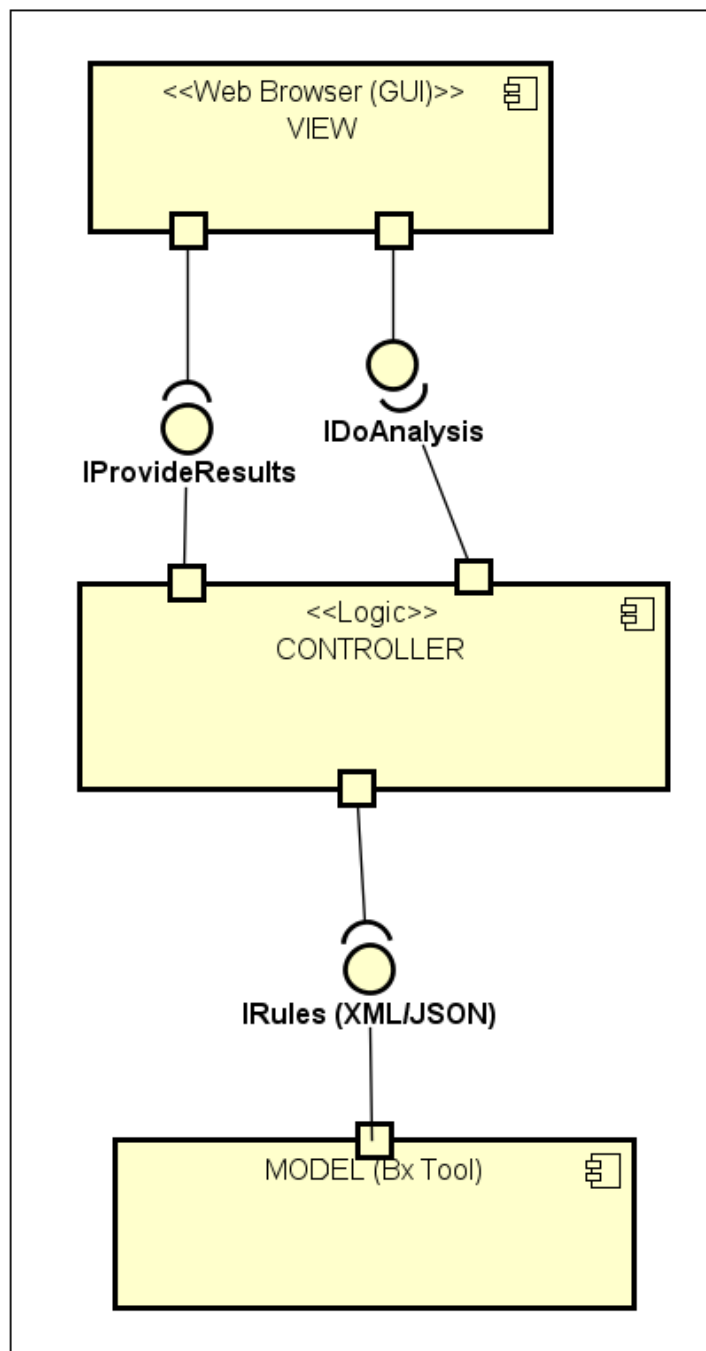


Figure 2: Component Diagram

7 Application

7.1 Application Walkthrough

8 Evaluation

8.1 Discussion and Feedback

8.2 Evaluation and Results

9 Summary

9.1 Conclusion

9.2 Future Work

10 Appendix

The Appendix can be used to provide additional information, e.g. tables, figures, etc.

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