

Improving feedback for a web-based marking system

Paul Thomson

Supervisor: Ewan Klein

Fourth Year Project Report

Software Engineering

School of Informatics

University of Edinburgh

2013

Abstract

This thesis will discuss the work done towards improving the feedback provided to users of the Infandango system.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

*(Paul Thomson
Supervisor: Ewan Klein)*

Table of Contents

1	Introduction	1
2	Background	3
2.1	Infandango	3
2.1.1	Current feedback	3
2.2	Literature	3
3	Design	7
3.1	Language and Tools	7
3.2	Proposed Design	7
3.2.1	Model	7
3.3	What next?	9
3.3.1	Integrating with Infandango	9
4	Evaluation	13
4.1	Objective Measures	13
4.2	User Feedback	13
4.3	Technical Difficulties	13
	Bibliography	15

Chapter 1

Introduction

Infandango is an open source web-based system for automated grading of Java code submitted by students[8]. The aim of this project is to improve the feedback provided to students by using machine learning methods to display a visual representation of their current progress. In chapter 3 the design process will be discussed, explaining why certain choices were made. The implementation of these decisions will be discussed in chapter ?? with evaluation and conclusion following.

Chapter 2

Background

2.1 Infandango

Infandango is an automated web-based marking system for student submitted programming exercises. A student can view the list of warm-up, optional and core exercises and choose to submit a file for one of them. This file is then compiled and tested by Jester in a sandbox. Between the web frontend and Jester there is a PostgreSQL database which stores which files have been submitted for which users and how these files performed on the JUnit tests.

2.1.1 Current feedback

The primary source of feedback in Infandango is displayed in Figure 2.1. Each submissions is marked with a set of JUnit tests and the fraction of these tests which are correct is displayed. This fraction is converted into a percentage and displayed on a green or red background depending on the value. More general feedback is also available which displays similar information but the results are displayed by week rather than by question.

2.2 Literature

Khan Academy[3] is a website which provides users with online education material:

Our online materials cover subjects ranging from math and finance to history and art. With thousands of bite-sized videos, step-by-step problems and instant data[1]

A blog post[7] written by David Hu about Khan Academy demonstrates that different feedback measures can affect user performance significantly. The original Khan Academy system required a user to get 10 consecutive exercises of a certain type correct before they can be deemed proficient¹ at that type of exercise. In an attempt to improve this system, a logistic regression model is used to calculate the probability that a user passes the next exercise successfully, with a threshold of 94% representing the new proficiency level. Over a 6 day period 10% of users tested the new method. Users of the new system earned 20.8% more proficiencies, attempted 15.7% more exercises and required 26% less exercises per proficiency. Hu summarises by saying the boost seems to come from allowing users to move on from exercises which they already proficient at, without requiring them to complete their streak thus wasting time on something they already understand.

¹A proficiency is earned when a user is deemed to be "proficient" at a certain kind of exercise

7 - [core]	Safer Fixed Divider	4 / 5	(80%)
8 - [core]	Safer Quadratic Solver	5 / 5	(100%)
9 - [core]	Squares Loop	12 / 13	(92%)
10 - [optional]	Lopsided Number Triangle	0 / 1	(0%)
11 - [optional]	Gambler's Ruin	0 / 2	(0%)

Figure 2.1: This is a crop of what will be displayed to the user for a given week

Chapter 3

Design

With promising results for machine learning based visual feedback a similar design could be made for Infandango.

3.1 Language and Tools

Two languages are immediate possibilities for implementation: Java[4] and Python[5]. I had most experience with Java, and some parts of Infandango were already written in Java. Most of Infandango was, however, written Python and I had some experience with it as well. After researching appropriate languages for machine learning R[6] become a third possible choice. Follow research on all languages Python seemed most appropriate: integrating with Infandango would be straightforward and scikit-learn[2] would remove the challenge of implementing machine learning methods.

3.2 Proposed Design

Using anonymised data from previous years a model can be built using machine learning methods to provide feedback. Using this model and some recent scores from the user, the following score can be predicted.

3.2.1 Model

The Khan Academy model is built based on one assumption: a user can always *generate another example* and it will be of the *same type*. These are two qualities which Infandango does not share. Infandango has a preset number of manually written exer-

cises and they are not grouped *strictly* by similarity. The first proposed model was to take the average for each week and use those averages as features for the model and the next week's average as the class. There are however some problems with this model:

- The semester has 8 weeks worth of exercises. If all 7 weeks are used as a feature and the score for week 8 is predicted then the user would not receive any feedback until the last week. If feedback is to be generated for each week then a separate model needs to be trained for each week: one model where there is only 1 week of evidence and week 2 is predicted, another where there are 2 weeks of evidence and week 3 is predicted and so on. Neither of these options are desirable.
- Even after 3-5 weeks there would only just be enough data to start getting reasonable results
- Grouping data like this means we have a lot less training examples

A similar alternative to this model is to treat each question within a week separately, giving the model a much larger dimensionality. Although this does remove the latter two problems, the first problem still remains. This also raises the likelihood of data being missing for a feature (it is more common for a student to miss one exercise within a week than the whole week).

Both of these models have been working with the assumption that we want to learn something about *specific* questions. So if, for example, a question was particularly hard then the model might be able to learn that it should predict lower scores for that question. However, we have seen the difficulties that these models incur. For this reason a much simpler model was created. The model has N features, each a percentage. Each feature represents a score from the corresponding previous question. The class is the score for the $N+1$ problem, so when a user is using the system it will try to predict their next score given their previous N scores. This creates a moving window of previous scores, with each feature simply being *a question* rather than, for example *week 3, question 2b*.

3.2.1.1 Unexplored Alternatives

There are many unexplored possibilities for other features like a weighted moving average or the number of problems unfinished. With this project it was important to complete the system quickly so that user tests can be done over a period of weeks.

Other possibilities for features and other learning methods can be explored in later projects.

3.2.1.2 Training the model

Django is used to retrieve the training data from the anonymised data from a previous year. This data is filtered into groups of $N+1$ consecutive results, with the final result being the class. For each set of K results $K-N$ sets of results are created. This provides the machine learning methods with a lot more training data than alternative models.

In order to decide which learning method to use sci-kit learn's cross validation method splits the data into training and testing sets, with a testing size of 20%. Different machine learning methods were then trained on this data and tested by comparing their R^2 scores. In Figure 3.1 it can also be seen that these tests are done multiple times over different values of N . The highest accuracy is obtained by Logistic Regression at $N = 4$. Logistic Regression is also the most consistent of the methods, thus making it the most appropriate choice.

3.3 What next?

In the next few weeks the system will be completed so that is fully functional for user testing.

3.3.1 Integrating with Infandango

To integrate with Infandango the model must be given the recent scores in order to update their predicted score and this must be used by the frontend to be displayed in some way.

3.3.1.1 Database

The functionality has already been written which queries the database for the most recent questions. It would be possible to do this without querying the database (store each new question in some temporary place) but for the limited amount of testing being performed any possible speed decrease (database queries can be slow) can be ignored. What is left is to put the code in the relevant place within the system.

3.3.1.2 Frontend

This is the area which will require the most work. The first step is to decide on the preferred design: how the predicted score will be displayed. When a number of designs have been drafted a group of students who used the system last year will be asked for which design they prefer. These designs are likely to be very visually, with little or no numbers. This is with the aim to abstract away from the marks being received and instead give the user an idea of how well they are performing: should they be working harder or are at a good stage right now?

When a design is decided the placement of the widget will need to be decided. It is likely to be placed on the side bar which contains the list of weeks and questions.

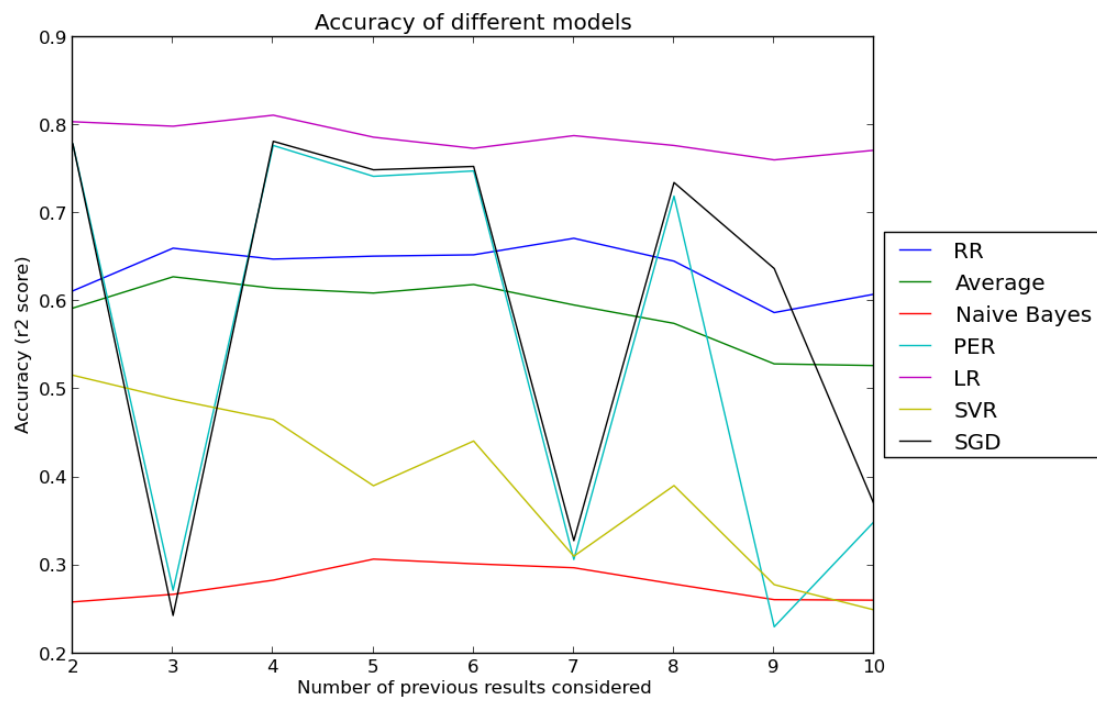


Figure 3.1: Comparison of different machine learning methods comparing their accuracy against the number of previous exercises considered

Chapter 4

Evaluation

By testing this new system on users who are also using the original system it should be possible to compare the two systems and measure how effective the new widget has been. Volunteers from the currently running course will be asked to use this system instead of the live system for certain weeks. Variations of this system may also be tested to see if different visual designs result in different progress.

4.1 Objective Measures

With users switching between systems and not every week being captured objective measures be less effective. Average score, number attempts and time taken to submit exercises can still be compared but careful consideration will need to be given to ensure accurate conclusions are drawn.

4.2 User Feedback

Users will be given questionnaires to complete for each system. The questionnaires will contain question asking about general use of the system, and if the widget helped their learning in any way. Here users can explain some designs were particularly motivating or if they had multiple interpretations.

4.3 Technical Difficulties

Since these tests are running alongside the course as it is running there are some things which must be taken into consideration. Since learning is being measured, the user

must use this system, for a given week, before the user has used the other system. Otherwise, the user will have already done the exercises. This means the files the user submits to this system must be transferred to the live system as well since it is unlikely the user would be willing to do all the exercises twice. The solution to this problem is yet to be decided but will most likely be asking the user to resubmit all their exercises in the live system at the end of the week. Efforts will be coordinated with the organisers of the course to limit problems for the user.

Bibliography

- [1] <http://khanacademy.desk.com/customer/portal/articles/337790-what-is-khan-academy->.
- [2] <http://scikit-learn.org>.
- [3] <https://www.khanacademy.org/>.
- [4] <http://www.java.com/>.
- [5] <http://www.python.org/>.
- [6] <http://www.r-project.org/>.
- [7] D. Hu. How khan academy is using machine learning to assess student mastery, Nov 2011. <http://david-hu.com/2011/11/02/how-khan-academy-is-using-machine-learning-to-assess-student-mastery.html>.
- [8] E. K. Mike Hull, Dan Powell. Infandango: Automated grading for student programming.