University of Glasgow | School of Computing Science

A Hands-on Approach to Learning Molecular Biology Techniques

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Level 3 Project —

Abstract

Abstract-like things

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Chapter 1

Introduction

1.1 Preliminaries

There are some terms that will be used later in the report that should be clarified now, so as to avoid confusion. The aim of the project is to creating a teaching tool for PCR, or Polymerase Chain Reactions. This is the process of amplifying a sequence of DNA thousands to millions of times. It should be explained that DNA sequences are made up of two strands, comprised of bases of the nucleotides Adenine, Thymine, Guanine and Cytosine, represented by the letters `a`, `t`, `g`, and `c` respectively. Base pairing is when one base bonds with its complement on the other strand. `a` and `t` complement each other, and G and C complement each other.
Primers, used to select the sequence for PCR in a given selection of DNA, are shorter fragments of DNA, usually between 20 and 30 bases in length. For use in PCR, a primer must be chosen from the left of one strand (this is the forward primer) and the right of the other (this is the reverse primer), and these must obey a number of rules, which are the focus of the teaching tool:

- The primer must not self-anneal. This means that if the primer were to fold in on itself in any way that more than 3 bases in a row on one side paired to the base on the opposite side, the primer would fold over and become useless.
- The melting temperature, calculated in degrees Celsius using a simple mathematical formula involving the frequency of `a`s, `t`s, `g`s and `c`s, must be between 50 and 65C, and within 2-3C of each other.
- It must be unique within the strand.
- The percentage of Gs and Cs within the sequence must be between 40% and 60%.
- The length should be between 20 and 30 bases.
- The same base should not be repeated several times in a row.
- The last base of the primer should be either a `g` or a `c`.
- The primers should not anneal to each other. This means that the rule is broken if, at any point in the overlap of the primers, more than 3 bases in a row paired with the overlapping primers base.

It should also be explained that we are developing the teaching tool in Java, using Netbeans, a free IDE primarily designed to be used with Java, and developing the user interface with Swing, the primary Java GUI widget toolkit.

1.2 Aims

The overall aim of this project is to produce a piece of software to help Molecular Biology students learn about PCR and Primer Design Techniques and to allow them to test their knowledge of these subjects. Initially, this overall aim was divided into key tasks to be completed and important aspects of the interface design to be implemented:

1. The software should work as an interactive tutorial which users can work through. This requires:

    - A number of areas for users to enter their own choice of data e.g. choice of primers. For this feature to be useful as an educational tool feedback must be provided upon data entry.
    - Users should be able to experiment with different data e.g. examining the different melting temperatures of different primers. This requires the ability to easily move forwards and backwards between the different stages of the tutorial.
    - To help newer users and students who are unfamiliar with PCR there should be simple instructions to tell users what to do on each page. There should also be a page displaying the rules of PCR and primer design which should be available at all times.

2. The software should be useable by all users, regardless of their different levels of knowledge, ability etc. This includes:

    - To achieve this, the interface should be uncomplicated and intuitive without compromising the required functionality. This will be aided by the instructions and help section mentioned above as well as labels placed next to any areas users can interact with.
    - Any section which makes use of colour should be designed with colour blind users in mind.

3. The software should improve upon the tools currently available for learning primer design. The main issues with these systems are:

    - The low level of interactivity offered by the systems. Users who are not actively working through a tutorial or a demonstration are likely to lose interest faster so it is important to make them involved with every step of the tutorial by having them design their own primers etc.
    - The available tools rarely go into detail about primer design specifically. Therefore, an important aim for the project is that primer design must be explained in high detail and provide enough information to be informative, whilst remaining interesting to students using the system.

4. Another aim related to accessibility is that the users should be able to download and use the software from home. This means that the program must be able to run on a variety of different operating systems and computers with varying performance levels. With this in mind it was decided that the program should be written in Java due to it being highly portable.

1.3 Background

1.4 Motivation

In order to understand the motivation for the development of the system, we were sent three links to systems currently in place which attempt to make learning this process more interactive and/or visual. However, videos and multimedia in general have been questioned as teaching aids in the past. Simply because the information is in video or multimedia format does not necessarily mean that it is benefitting the learning of its viewers, or creating the correct environment to encourage learning. Interactivity, along with other factors, are key to engaging people to learn (DeKanter, 2004).

The first was a video hosted on YouTube ('dwildridge', 2012), made by demonstrators within the School of Life Sciences. During its eighteen second duration, the video shows various elements of the PCR process including change in temperature and the role of the primer. However, it was commented by the team and by the clients that it was insubstantial in terms of information delivery, several of the stages of PCR are omitted with no mention of primer design, and in terms of interactivity.

Another video hosted on YouTube ('DNALearningCentre', 2010), currently referred to on School of Life Sciences' website, is similar in style to a lecture with slides and a voice-over which repeats the textual information on each slide. While this video is far more informative than the previous one, with each stage of PCR clearly described, and with visually pleasing animations, it lacks in explicit primer design and again in interactivity.

Finally, an animation from the University of Utah, titled "PCR Virtual Lab" (Genetic Science Learning Center, 2012). This is a much more interactive experience and allows the user to use virtual pipettes in order to simulate what you would do in a lab situation when performing PCR. Additionally, the information it provides, while slightly basic in the beginning for our target users, is extensive and very informative to the novice user, such as Biology-illiterate Computing Scientists. While this is a much more interactive and, compared to the alternatives described above, much more informative experience, it fails to provide the user with the theoretical background information, particularly on primer design, required to fully understand the process and why the reaction occurs.

Chapter 2

Design

Chapter 3

Implementation

Chapter 4

Evaluation

Chapter 5

Conclusion

Chapter 6

Contributions

Bibliography

Nick DeKanter. Gaming redefines interactivity for learning. *TechTrends*, 49(3):26–31, 2004.

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