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Employing Machine Learning Techniques for Offering Dynamic Trajectories on Education Coding Platforms

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Chapter 1

Problem statement

Educational platforms for learning programming languages offer their service very often in a rather static way, where the learner's trajectory is fixed once they are enrolled in a course. However, this should ideally be adjusted to ensure that more adept learners are not demotivated by the materials being too simple. The same could be said for slower learners, who should follow a trajectory with more repetition.

The main objective of this thesis is therefore to develop a system that will adapt a learner's trajectory dynamically, based on their performance. To create such a system, as well as to evaluate its performance, an online learning platform is required. Here, E-Systant comes to the rescue.

1.1 E-Systant

E-Systant is an online learning platform, developed at KU Leuven. It is used in the 'Declarative languages' course of the Computer Science program, where it is used to teach both a logical programming language (Prolog), and a functional programming language (Haskell). The platform is in use since 2016 and has been used by more than 1500 students. This way, it has accumulated a lot of valuable data, which will turn out to be useful for the development of the adaptive system. An important note, however, is that a new data submission entry is created only when a student submits their code for evaluation. As a consequence, detailed information about the student's progress on a small time scale is not available.

1.2 Adaptive learning

1.2.1 Recommending the next programming assignment

One of the ways in which adaptive learning will be achieved is by giving recommendations for the next programming assignment that should be undertaken. For giving these recommendations, neural network models will be used, trained on the historical data of E-Systant. Alongside this, we will investigate if deep reinforcement learning techniques can improve the overall performance of the recommendations.

Classical neural network based models

In a first stage, the models will be trained with as only input features the available submission data [1]. In a second stage, these models will be extended with additional features, created after some feature engineering. An example of such an additional feature will be a created skills portfolio, that captures how well a student grasps certain concepts of the course.

Most literature on the subject of adaptive learning in e-learning settings uses either collaborative filtering or content-based recommendation, as summarized in [1]. However, deep learning approaches to adaptive learning are currently not very common. In [2], a recommendation framework based on deep learning is proposed, but no concrete implementation or actual results are given. Nonetheless, deep learning recommendation models are being applied in lots of other domains, as follows from the literature survey of [3]. This thesis, therefore, investigates how these deep learning models can be applied in the e-learning context.

Skills portfolio Conceptually, the skills portfolio should initially be a vector in a space with as many dimensions as there are concepts in the course. The length of the vector in a certain dimension should then indicate how well the student understands that concept. However, since concepts will not be orthogonal to each other, a further optimization will be to use an embedding space, where concepts can be related to each other. Afterwards, the embedding space should be projected to a lower dimensional space, so that the skills portfolio of a student can be visualized to both the student and the teacher.

We don't want the concepts of the skills portfolio to be data-driven, since the skills portfolio itself will be used as an extra input feature in the neural network. Instead, we will annotate the programming assignments with the concepts that are being taught in that assignment. Example concepts could be rather low-level, such as 'pattern matching', and 'higher-order functions', or more high-level, such as 'the student is able to compose different concepts'.

Building learner profiles have been done by [4] and [5], but they focus more on profiling the learner's attitude, instead of their acquired skills. To the best of our knowledge, no other work has been done on creating a skills portfolio for a student, based on their performance on programming assignments. Creating such an overview of the acquired skills, along with a visualization for the user and the teacher, seems to us like a valuable addition to the E-Systant platform.

Deep reinforcement learning

Besides classical machine learning techniques, deep reinforcement learning will also be tried out to give recommendations. The idea is that states should represent the completed assignments, while an action should represent which assignment should be tried out next. Rewards are the points that the student has earned on the assignment.

[1] Each submission contains a timestamp, the submitted code, how many points that have been earned, and the time it took the server to execute the code.

In [6], it is elaborated how reinforcement learning can be used in e-learning settings. Furthermore, in [7] and [8], classical Q-learning is being used, while [9] actually uses deep reinforcement learning. Hence, here the thesis will investigate how well their results can be replicated in our context, and how the results with deep reinforcement learning compare to the classical deep learning techniques.

1.2.2 Recommendation in the reviewing phase

Another way in which the learner can get adaptive feedback is by offering the learner insights into the concepts they are struggling with the most. Furthermore, in a reviewing phase (say, when they are preparing for the exam), specific programming assignments can be recommended to the learner, in order for them to fill the knowledge gaps as efficiently as possible. This feature will rely heavily on the previously mentioned skills portfolio, from which the learner's strengths and weaknesses can be determined.

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