Online Tests and Predictive Analytics

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Abstract—We present a framework that estimates students' exam performance in the context of mathematics lectures. For the prediction, we apply a multi-variate nonlinear regression implemented in MATLAB based on the results of five tests acting as independent data. The electronic tests were implemented by means of online assessment system STACK. The tests cover all major topics and are evenly distributed throughout the lecture period. The performance of the approach is quantitatively tested on student groups. In the future, the insights gained in this way will serve as a starting point for prespective analytics.

Keywords—STACK, online assessment, learning analytics, predictive analytics, multivariate nonlinear regression

1 Introduction

In the initial study period, some of the undergraduates have difficulty adjusting from the school system to the university system. This is reflected in particular in the examinations which take place after the lecture period. From our point of view, however, the learning assessment as well as the feedback on the learning processes need to be performed at an earlier time. Therefore, we have introduced voluntary tests in the winter semester 2018/19 in the mathematics lecture in the 1st semester, with which students can achieve a 10% bonus to the exam grade. In order to keep the effort for the implementation and assessment of the tests low, we implemented them in STACK – one of the world-leading open-source online assessment system for mathematics and STEM fields, i.e. Science, Technology, Engineering and Mathematics. STACK is available as a plugin which includes a question type for the Moodle Virtual Learning Environment and also as a question type for the ILIAS system. It can be used in other systems via the Learning Tools Interoperability protocol, as stated in [8], [10]. STACK owes its analytical capability to the computer algebra kernel MAXIMA [1], [4]. We use the electronic tests set up in sense of learning analytics, see e.g. [2], not only to assess the current learning status of students, but also to estimate students' exam performance in advance. For this purpose, we set up a nonlinear multivariate model using the data collected in the winter semester 2020/21 (134 students) by means of the MATLAB programming environment, see [6], and tested it on the 87 exam takers of the winter semester

2021/22. A prediction tool, such as one based on neural networks, see e.g. [12], would not be appropriate for our case because we have a relatively small amount of data and aimed for an easy-to-use system.

2 Data sets and the regression model

The learning setting consists of 5 online tests, each composed of about 10 tasks that are significant for the learning processes and focus on procedural knowledge, see e.g. [7]. For each test, 20 scores can be achieved, for a total of 100 scores. 100 variants of each test have been generated using STACK, so that every student receives an individual test that may be worked on at home. The tests take place every two weeks and the processing time is also two weeks.

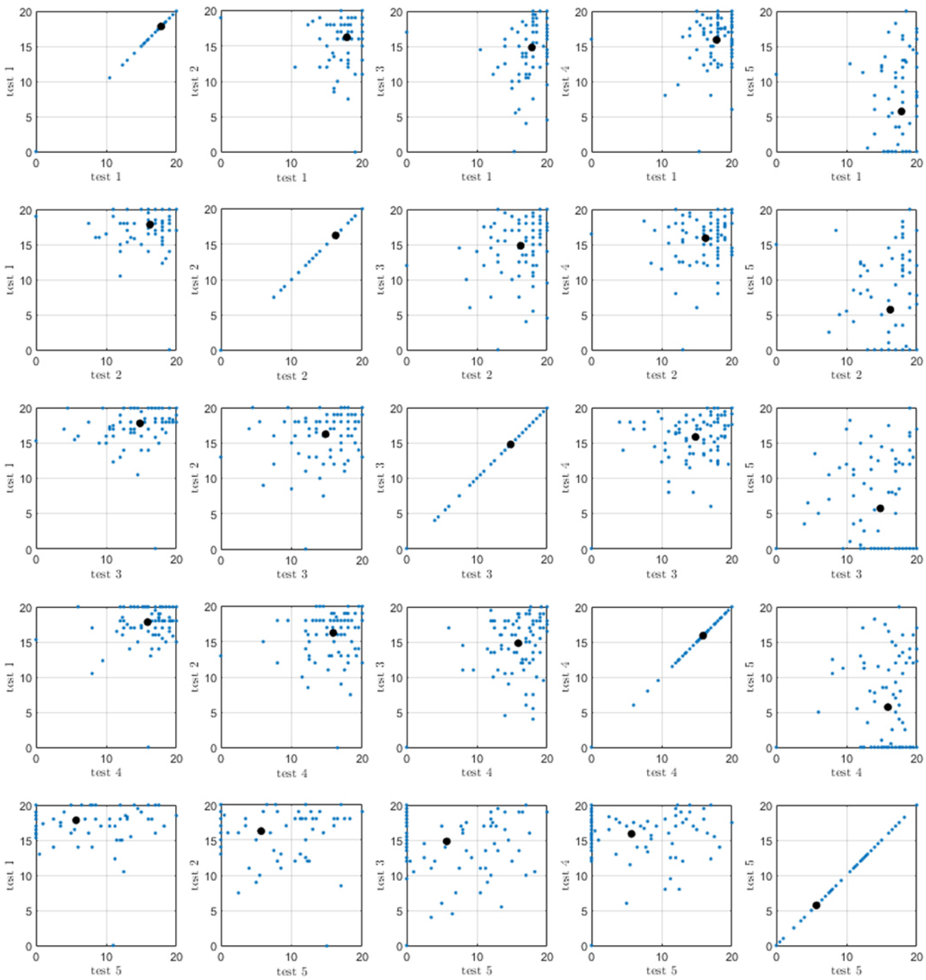

Fig. 1. Scatter plot matrix for the scores of the 5 tests carried out in winter semester 2020/21; The statistical emphasis of the respective scatter plot is marked in black

We set the evaluation scores of the five tests of 134 students, cf. a corresponding scatterplot matrix in Figure 1, to a data vector $\vec{X} \in [0,\ldots,20]^5$ that acts as an independent variable of the nonlinear multivariate regression function $R(\vec{X}) = Y$ to be determined. Here, $Y \in [0,\ldots,60]$ is the student's exam score to be estimated, i.e., a maximum of 60 scores can be achieved in the exam. We predefine the regression function as a 2nd degree polynomial with the variables X_1, X_2,…, X_5. This results in a polynomial with 21 summands. We determine its coefficients from the data of the 134 students from the winter semester 2020/21, i.e., the tests and the exam results were applied. For the software implementation of the approach we use the programming environment MATLAB and in particular the MATLAB-function "regress", see e.g. [9]. Due to the high dimension of the independent variable $\vec{X}$ the graph of the polynomial cannot be fully represented. However, if one restricts the polynomial to two variables, e.g. X_1 and X_2, one gets an impression of the calculated regression function, see Figure 2.

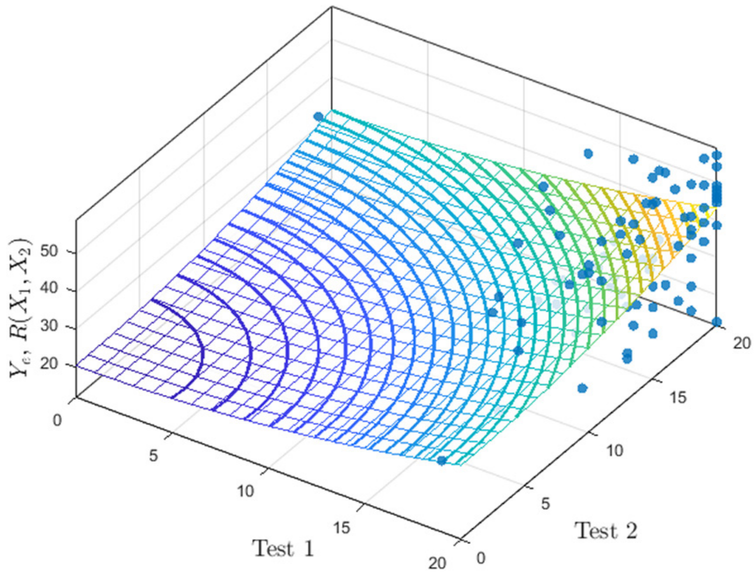

Fig. 2. Regression polynomial restricted to the dimensions X_1 and X_2, see surface plot; scores achieved in the test 1, test 2 and exam, see scatter plot

3 Results

We apply the regression function set up above to the tests of the 87 students from the winter semester 2021/22 in order to estimate their exam results in advance. The residual between the exam result Y_e and the estimated exam result $R(\vec{X})$, i.e. $Y_e - R(\vec{X})$ is shown in Figure 3.

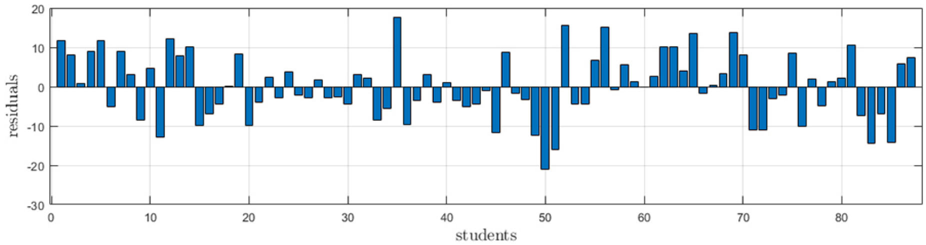

Fig. 3. Residuals between the exam scores and the estimated exam scores of 87 students

The empirical standard deviation for this data set is $s = 8.1$ scores and the empirical mean is $\bar{x} \approx 0$. Assuming a normal distribution of the residual with the mean $\mu = 0$ and the standard deviation $\sigma = 8.1$ the two-sided 50% error band for the exam performance to be estimated yields the interval $\left[\mu - z_{1/2}\sigma, \mu + z_{1/2}\sigma\right] \approx \left[-5.5, 5.5\right]$, see e.g. [3]. This means that for half of the students the exam grade can be estimated with a maximum deviation of 5.5 scores. Thus, for an exam of 60 scores, the deviation represents less than 10% of the maximum exam performance. For the two-sided 75% error band one obtains [–9.3, 9.3].

4 Future perspective

The analysis of the data shows that it might be better to divide the students into two clusters (sum of the commulative test scores up to 80 and over 80) and set up a regression model for each cluster individually. Furthermore, we plan to add participation in lectures and learning activities (e.g. via login data in Moodle) as additional independent variables of the regression. After establishing predictive analytics, we would like to expand this tool with the prespective analytics component for better understanding of learning processes and to support lecturers with automatic recommendations for appropriate interventions and personalized tutoring, see e.g. [5], [11].

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6 References

[1] Computer Algebra System MAXIMA. Available: https://maxima.sourceforge.io/. Accessed September 21, 2022.

[2] ElAtia, S. (Editor), Ipperciel, D. (Editor), Zaiane, O. R. (Editor), *Data Mining and Learning Analytics: Applications in Educational Research*, Wiley, 2016. https://doi.org/10.1002/9781118998205

[3] Fahlmeir, L., Heumann, Ch., Künstler, R., et al. (2016). *Statistik – Der Weg zur Datenanalyse*, 8. Auflage, Springer Spektrum. https://doi.org/10.1007/978-3-662-50372-0
[4] Haager, W. *Computeralgebra mit Maxima: Grundlagen der Anwendung und Programmierung*, Fachbuchverlag Leipzig im Carl Hanser Verlag, 2014. https://doi.org/10.3139/9783446437302
[5] Liu, M., Zhang, Q. (2019). Evaluation of Student Performance with Predicted Learning Curve Based on Grey Models for Personalized Tutoring, *International Journal of Emerging Technologies in Learning (iJET), 14*(13), pp. 157–171. https://doi.org/10.3991/ijet.v14i13.9880
[6] MathWorks, MATLAB. Available: https://de.mathworks.com/products/matlab.html. Accessed October 3, 2022.
[7] Mündemann, F., Fröhlich, S., Ioffe, O., et al. "Kompetenzbrücken zwischen Schule und Hochschule", *Lehren und Lernen von Mathematik in der Studieneingangsphase*, Herausgeber: A. Hoppenbrock, R. Biehler, R. Hochmuth, H.-G. Rück, Springer, 2015. https://doi.org/10.1007/978-3-658-10261-6_21
[8] STACK (System for Teaching and Assessment using a Computer algebra Kernel), Available: https://stack-assessment.org. Accessed October 3, 2022.
[9] Schweizer, W. *MATLAB kompakt*, 5. Auflage, Oldenbourg Verlag, 2013. https://doi.org/10.1524/9783486735949
[10] The University of Edinburgh, STACK – System for Teaching and Assessment using a Computer algebra Kernel. Available: https://www.ed.ac.uk/maths/stack. Accessed September 21, 2022.
[11] Zhang, L., Zeng, X., Lv, P. (2022). Higher Education-Oriented Recommendation Algorithm for Personalized Learning Resource, *International Journal of Emerging Technologies in Learning (iJET), 17*(16), pp. 4–20. https://doi.org/10.3991/ijet.v17i16.33179
[12] Zhang, Y., Jiang, W. (2018). Score Prediction Model of MOOCs Learners Based on Neural Networks, *International Journal of Emerging Technologies in Learning (iJET), 13*(10), pp. 171–182. https://doi.org/10.3991/ijet.v13i10.9461

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