DE GRUYTER OPEN

ICTE Journal

2017, **6**(2): 5–11
DOI: 10.1515/ijicte-2017-0007

ADAPTIVE CONTROL STRATEGY IN CONTEXT WITH PEDAGOGICAL CYBERNETICS

Tomáš Barot

Department of Mathematics with Didactics, Pedagogical Faculty, University of Ostrava, Mlýnská 5, Ostrava, 701 03, Czech Republic {Tomas.Barot@osu.cz}

ABSTRACT

In this paper, the practical aspects of the pedagogical cybernetics are described. A generally known feedback model of an educational process is modified for the purposes of a student knowledge support in the mathematical education. This modification is connected with the corresponding area of the technical cybernetics. These principles can be situated in the pedagogical area with the similar aims as in a processes control. A proposed model of an adaptive control is recommended as a suitable form of an interaction between a student and a teacher. Although this approach can be time-demanding, its appropriate advantages can be utilized in favor of practice in an individual consultation. In this paper, the described proposal of the advanced control model is supported by a free-available software. The application of this proposed strategy was practically realized in the author's consultations at the Maths Support Centre at the Faculty of Applied Informatics at the Tomas Bata University in Zlin.

KEYWORDS

Adaptive control strategy, cybernetics, feedback model of education, consultations, mathematics, free-available mathematical software.

1 INTRODUCTION

In the pedagogical cybernetics (Granic et al., 2009; Gushchin & Divakova, 2015), a generally known model of an educational process has a feedback form, as can be seen in (Cevik et al., 2015). A teacher and a particular student can be situated in this process by the abstract models. In a modular view on the modelled educational process (Granic et al., 2009), the connection between a student and a teacher has the specific feedback form. In a plenary lecture, a feedback connectivity it is not always applicable. In a seminary, this feedback functionality can suitable achieve the aim of this educational strategy.

In the field of simulation (Corriou, 2004), a model should be characterized by the important parameters. This declared model can substitute a real object (e.g. a student in the pedagogical cybernetics) with respect to its significant attributes (e.g. a knowledge level of a student in the pedagogical cybernetics). A method for a determination of these parameters is identification (Nelles, 2001). The identification should be performed in an initial part of a feedback process. Then an interaction between considered objects can be suitable stated in the feedback approach to education.

The pedagogical cybernetics fulfills similar aims as the technical cybernetics (Kučera, 1991) in which the models are described by a mathematical background in a form of a differential equation (Balátě, 2004). The identification process may be realized online (Corriou, 2004) or offline (Ingole et al., 2015). In each time

of a technical feedback control of a process, a controlled object can be repeatedly identified. This specific type of a process control is denoted as an adaptive control strategy (Bobál et al., 2013). This method is very important in case of the time-variant parameters of a controlled model. This problem can be described by a differential equation with the time-variant parameters (Balátě, 2004) in the mathematics.

In the pedagogical cybernetics, a principle of the adaptive control can be applied in an analogical form. However, this principle is not strictly based on the mathematical background. In this paper, the strategy of the adaptive control is presented in the context of an educational practice. This proposed repeating form of an identification process in the feedback model of a learning strategy may be applied in an educational process. However, this concept brings a disadvantages based on a recurrent time-demanding interaction between a student and a teacher. For this reason, the recommended application may be having a form of the individual consultation of student. In this paper, the practical application of the proposal is demonstrated in the author's consultations at the Maths Support Centre at the Faculty of Applied Informatics at the Tomas Bata University in Zlin presented in (Pátíková, 2016). In this type of an education centre, a greater count of students may come visit the tutor. Therefore, a second advantage of the proposed approach is a decreasing of time of a problem-explanation with the required quality.

2 METHODS AND PROPOSED MODIFIED STRATEGY

Generally Used Method of Feedback Model in Pedagogical Cybernetics

A feedback model of an educational process is widely described in (Cevik et al., 2015) and can be seen e.g. in Fig. 1 in a form of a mathematical education. This control strategy is based on the same principles as in case of the technical cybernetics (Kučera, 1991).

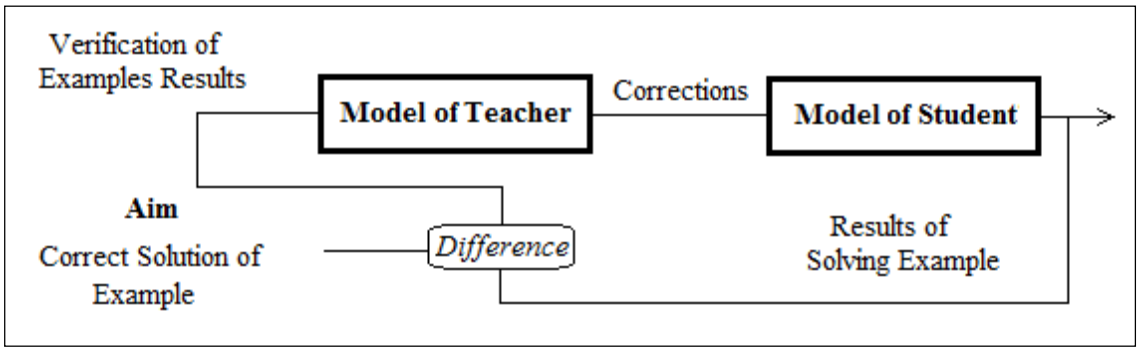

Figure 1 Feedback Model of Educational Process with Example in Mathematics

A student or a teacher is in this context substituted by an abstract model in the pedagogical cybernetics. In comparison to the technical cybernetics, the models are only moreover described by a mathematical background e.g. by a differential equation in (1). Variable t represents time, where $t>0$ for purposes of consideration of physical causality ($m < n$). Variable y expresses output information from the control model (e.g. student). An interaction between the considered models is performed by variable u in the equation (1). The feedback model (Fig.1) is characterized by the constant time-invariant parameters $a_i, b_j, i \in \langle 0,..,n \rangle, j \in \langle 0,..,m \rangle$. An order n of a differential equation is usually equal to 2 in the most of practical applications.

$$a_n y^{(n)}(t) + ... + a_1 y'(t) + a_0 y(t) = b_m u^{(m)}(t) + ... + b_1 u'(t) + b_0 u(t) \quad (1)$$

Variable y can represent information which is presented by the student. The corrections u for the students are expressed by the teacher. Variable u is then determined by the teacher.

These signal variables are not in a humanistic area further used; however, the connectivity between the two areas of cybernetic is demonstrated.

The model of student is very simple identified in this type of an educational process. Therefore, an adaptive control strategy may be suitable used for these purposes.

Proposal of Utilization of Adaptive Control Strategy in Context with Pedagogical Cybernetics

In the pedagogical cybernetics (Granic et al., 2009; Gushchin & Divakova, 2015), the adaptive control principle (Bobál et al., 2013) based on feedback strategy may be considered; however, this proposal is not widely described in the literature.

In the adaptive approach, a controlled model (e.g. a student in the pedagogical cybernetics) can be generally described as an abstract object with a time-variant structure. This change of a model behavior is defined by the non-constant parameters of the model in the technical cybernetics, as can be seen in equation (2). Because a dynamics of the model is changing, a structure defined by parameters should be repeatedly identified (re-identified). Differences of equations (1) and (2) are based on the time-variant parameters a_i and b_j.

$$a_n(t)y^{(n)}(t)+\ldots+a_1(t)y'(t)+a_0(t)y(t)=b_m(t)u^{(m)}(t)+\ldots+b_1(t)u'(t)+b_0(t)u(t) \tag{2}$$

In the pedagogical cybernetics, a repeatedly identification (Corriou, 2004) may be an analogical process as in the technical cybernetics. The possibilities of a model re-identification may be consisted of a testing of a student on its knowledge. In the environment of a high school, this method can be time-demanding with consideration of a higher number of the students in a lesson. An appropriate environment for an application of the adaptive control strategy can be an individual consultation of a student, as is further discussed in this paper.

Proposal of Adaptive Control Strategy in Favor of Education of Mathematics

A disadvantage of a repeatedly identification is a time-demanding property in the adaptive control strategy in the feedback cybernetics model. This problem can be eliminated e.g. using information technologies. The particular solution can be an application of free-available mathematical software. The implementation of the proposal of the adaptive control strategy in a mathematical educational process in sense of the feedback control can be seen in Fig. 2.

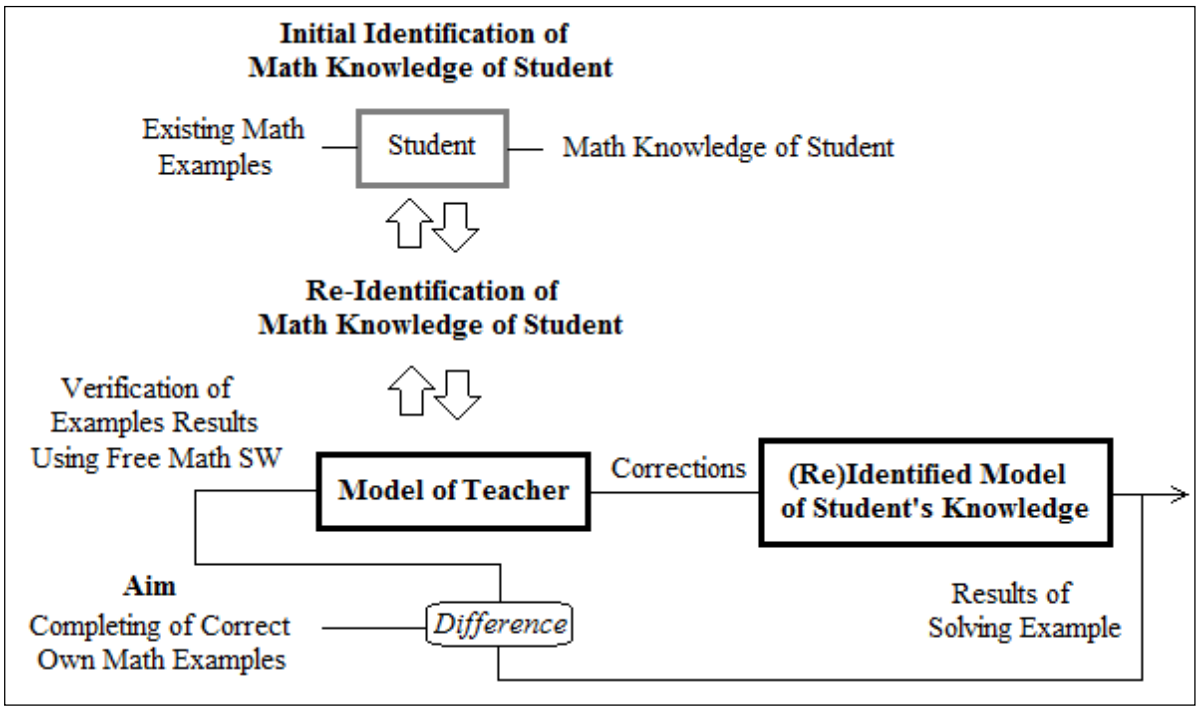

Figure 2 Proposed Model Focused on Example of Mathematical Practice

The re-identification of the particular student knowledge can be supported by these practical software possibilities. The aim of the acceleration of the time-demanding re-identification may be fulfilled. Further, a free based software (e.g. Octave, wxMaxima, SciLab, etc.) can be used at home by the students and can suitable improve their skills.

Free-Available Mathematical Software Tools as Support of Proposed Approach

In case of a linear algebra or a mathematical analysis, the MS Excel may not be a full-complete solution for learning. However, the most used functions for matrices processing are available. The main difference of using of these functions is an evaluating by a key-shortcut *Ctrl+Shift+Enter* instead of *Enter*. In this computational environment, the symbolical and numerical calculations are not implicitly aggregated. This type of calculations may be suitable solved in the further free-available softwares.

The free-available programs Octave and wxMaxima fulfill a purpose of symbolical calculations. Octave can be used as a support for the control-system theory as well. In this application, the symbolical toolboxes (e.g. for operations with polynomials) are included. For the symbolical computations in mathematics is appropriate the software wxMaxima too. In both programs, all operation for matrices are supported. Example of the elementary operations with matrices can be following commands: *inv*, *det* or *roots* for a determination of the polynomials roots.

In the free-available software PAST (Hammer et al., 2001), the essential statistical computations are provided. The elementary statistic characteristics (e.g. a sample mean value μ, a standard deviation σ^2) and hypothesis testing (Cortes, 2016; Kitchenham, 2016) for n data variables $X_i; i = \{1,...,n\}$ (in form of equations (3) or (4)) can be recommended to the students of statistics. The conclusions of normality and a hypothesis testing are based on interpretation of a significance value p calculable in this software. The null hypothesis H_0 is rejected in favor of the alternative hypothesis in case when the found significance value p

is greater than a pre-defined significance level α. The rule for the significance level is that α is usually equal to 0.05 in the pedagogical research.

$$H_0 : \mu_1 = ... = \mu_n;\ H_1 : \mu_1 \neq ... \neq \mu_n \tag{3}$$

$$H_0 : \sigma_1^2 = ... = \sigma_n^2;\ H_1 : \sigma_1^2 \neq ... \neq \sigma_n^2 \tag{4}$$

The important problem before an application of a statistical method for a purpose of the hypothesis testing is a determination of a probability distribution of the research *n* data variables X_i. On the normal distributed data ($X_i \sim N;\ i = \{1;n\}$) could be applied the parametric methods (Cortes, 2016; Kitchenham, 2016), in the opposite case ($X_i \not\sim N;\ i = \{1;n\}$) may be used the non-parametric tests (Cortes, 2016; Kitchenham, 2016). The normal probability distribution of data can be tested by Shapiro-Wilk test (Alizadeh Noughabi, 2016).

The advantage of the PAST is a complex software solution based on a table-cells layout. The office programs include the additional tools for hypothesis testing. The principles are based on the same principle of the calculation of significance value *p*. Software PAST is free-available and suitable for students. The advanced functionality of this program can be utilized by researchers as well.

3 RESULTS AND DISCUSSION

The proposed strategy was practically realized at the Maths Support Centre at the Faculty of Applied Informatics at the Tomas Bata University in Zlin. The author of this paper is a member of a team of the voluntary tutors under the leadership of Mgr. Zuzana Pátíková, Ph.D. (Pátíková, 2016).

In the author's consultations of students in the mathematical preparation, the proposed adaptive control strategy of teaching was applied. The identification of the student knowledge was performed in the initial parts of the learning sessions. Explained mathematical problems were linear algebra, mathematical analysis, linear differential equations and advanced statistical methods.

The identification was realized using the examples of several elementary problems in the particular area. The notices of students were controlled. Using free-available mathematical programs, the adaptive educational process with the re-identification achieved the aims of the individual consultations.

In the terms of the cybernetics, a model of a student was analyzed and its knowledge level was then repeatedly identified. The time-demanding identification may be possible in this individual form of an education. The free-available software for purposes of math learning can save this useful time. The most used software applications were: for statistics - PAST, for linear algebra - Octave and for the symbolic computations - wxMaxima. Using the student-knowledge identification, the consultations can be specific and the problems can be suitable solved.

The particular number of students in the consultations was approximately 15 with some repeated visits. Students had mostly a distance form of study. Lessons were provided on Saturdays. The field of a study of these students had a different spectrum; however, the study contained the mathematical focused background.

Each student of the consultations denoted that the possibilities of using of the free-available mathematical software are foreign to them. After the short tutorial, they denoted an advantage of a free-availability of the software. The matrix functions in MS Excel were unknown to them. On the repeated visits, the students appreciate these software products. In save time, number of the mathematical examples was computed by

students. With the most positive evaluation, the free software PAST was denoted for its comfortable functions for the statistics.

One student regularly repeated the learning sessions in the complex preparation on the thesis focused on a statistics research in a health care. The main software support was PAST. The solved problems were a normality testing and a testing of the hypotheses. The normality of data was determined by the Shapiro-Wilk test in PAST. For the hypotheses testing based on a comparison of the mean values, the Mann-Whitney and Kruskal-Wallis test were provided, because data had not a normal probability distribution.

Ten students wanted to explain the linear algebra problems. In the consultations, the own examples were constructed by the students with a verification in the denoted free-available softwares. Matrices were discussed and an inverse matrix or determinants were manually expressed. Determinants of a higher order were solved using the Laplace theorem. The control mechanism for these purposes was an algebra program Octave.

Four students wanted to prepare to the differential and integral calculus. The further exercised problem was the particular type of the linear differential equations solved in the written form and on the board. Many examples were realized on the symbolic principle in the wxMaxima in favor to the adaptive control strategy of learning in the mathematical consultations.

In these cases, the proposed strategy (Fig.2) with the described software support was realized on the principle based on the adaptive control. Utilization of this method was very usefull and achived a dynamical educational process of the individual consultations at the Maths Support Centre.

CONCLUSION

The adaptive control strategy of an educational process was described and utilized in the author's consultations at the Maths Support Centre at the Tomas Bata University in Zlin, where the author of this paper is a voluntary tutor. In the practice, the students were repeatedly identified by a teacher in favor of an improving of its knowledge using the adaptive control strategy. The support of the realized teaching strategy is in a form of a free-available mathematical software, which can spend time in the consultations. In case of a greater number of students with different topics in the consultations, the proposed strategy has an accelerating aspects. The main aim was to point out the possibilities of a wide application of the cybernetics principles of the technical cybernetics and its advanced strategies. The pedagogical practice can be based on these principles which can be applied in the area of the pedagogical cybernetics. Further strategies can be inspired by the technical cybernetics in the proposals in the future research. This paper can be considered as an initial qualitative research of the utilization of the practical aspects of the cybernetics principles. In the further research, the quantitative research may be realized.

REFERENCES

Alizadeh Noughabi, H. (2016). Two Powerful Tests for Normality. *Annals of Data Science*, *3*(2), 225-234. doi:10.1007/s40745-016-0083-y

Balátě, J. (2004). *Automatické řizení*. Prague, Czech Republic: BEN - technická literatura.

Bobál, V., Kubalčík, M., Dostál, P., & Matějíček, J. (2013). Adaptive predictive control of time-delay systems. *Computers & Mathematics with Applications*, *66*(2), 165-176. doi:10.1016/j.camwa.2013.01.035

Cevik, Y. D., Haslaman, T., & Celik, S. (2015). The effect of peer assessment on problem solving skills of prospective teachers supported by online learning activities. *Studies in Educational Evaluation*, *44*, 23-35. doi:10.1016/j.stueduc.2014.12.002

Corriou, J. P. (2004). *Process control: Theory and Applications.* London, United Kingdom: Springer.

Cortes, J., Casals, M., Langohr, M., & Gonzalez, J. A. (2016). Importance of statistical power and hypothesis in P value. *Medicina Clinica*, *146*(4), 178-181. doi:10.1016/j.medcle.2016.04.057

Granic, A., Mifsud, Ch., & Cukusic, M. (2009). Design, implementation and validation of a Europe-wide pedagogical framework for e-Learning. *Computers & Education*, *53*(4), 1052-1081. doi:10.1016/j.compedu.2009.05.018

Gushchin, A. & Divakova, M. (2015). Trend of E-education in the Context of Cybernetics Laws. *Procedia-Social and Behavioral Sciences*, *214*, 890-896. doi:10.1016/j.sbspro.2015.11.747

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, *4*(1). Retrieved from http://palaeo-electronica.org/2001_1/past/issue1_01.htm

Ingole, D., Holaza, J., Takacs, B., & Kvasnica, M. (2015). FPGA-Based Explicit Model Predictive Control for Closed Loop Control of Intravenous Anesthesia. *20th International Conference on Process Control (PC), Strbske Pleso, Slovakia, 9.-12.6.2015* (pp. 42-47). doi:10.1109/PC.2015.7169936

Kitchenham, B., Madeyski, L., Budgen, D., Keung, J., Brereton, P., Charters, S., & Gibbs, S. (2016). Robust Statistical Methods for Empirical Software Engineering. *Empirical Software Engineering*, 1-52. doi:10.1007/s10664-016-9437-5

Kučera, V. (1991). *Analysis and Design of Discrete Linear Control Systems.* Prague, Czech republic: Nakladatelství Československé akademie věd.

Nelles, O. (2001). *Nonlinear System Identification.* Berlin, Germany: Springer-Verlag.

Patíková, Z. (2016). Podpůrná centra pro výuku matematiky na vysokých školách. *Setkání učitelů matematiky všech typů a stupňů škol 2016, Plzeň*, (pp. 97-100). Pilsen, Czech Republic: Vydavatelský servis.