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COMPUTER SCIENCE MEETS AUTOMATION

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

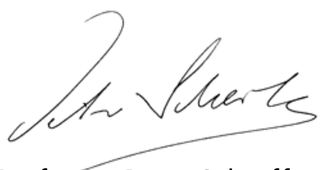
- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



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Professor Christoph Ament
Head of Organisation

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Technische Universität Ilmenau
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A. Fleischer / R. Andreev / Y. Pavlov / V. Terzieva

An Approach to Personalized Learning: A Technique of Estimation of Learner's Preferences

INTRODUCTION

The term "e-learning" presents "technology enhanced learning". It describes the use of computer-based technologies to support and enhance learning practice. The focus of e-learning engineering is on the design and implementation of e-learning environment. There are two approaches to the development of an e-learning environment that take into consideration two of its aspects. According to the first aspect, e-learning environment is a server that provides learners with learning objects and services. The approach concerning this aspect bases on service-orientated design and implementation models in the development of e-learning environment. Such environment consists of two fundamental types of servers:

- Servers that provide learning content (content providers);
- Servers for provision of learning services - the learning services support various learning styles, which correspond to the existing pedagogical methods.

The second approach considers e-learning environment as environment that supports educators in process of producing of learning resources that are composition of learning objects and services. It ensures the development of *production-oriented (productive) e-learning environments.*

Personalized learning concerns learner-centered adaptation of learning resources. In the web-based e-learning environment the process of personalization of learning objects requires *model of an individual learner* that represents its profile [6]. This model is an element of adaptive e-learning environments that carry out various adaptation methods. Some of them use semantic-based reasoning for achieving automatic adaptation of e-learning environment [1]. Others utilize to the fullest extent reasoning that bases on matching learning material described by metadata with learners' characteristics. A service-based strategy for implementation of an adaptation method of reasoning that uses heuristic rules for deriving recommendations using learner profile information model is presented in [7]. The adaptive servers providing learners with educational services are personalized, as well. An approach to personalization of adaptive learning services provision is given in [8]. A model of personalization of an adaptive e-learning environment that provides learning objects and services together is presented in [2].

The adaptation of learning resources to individual learners in a productive e-learning environment bases on transformation of generalized learning resources into specific ones. This is an adaptation technique, which bases on *generalization/specification* method of reasoning and determines the e-learning environment as “adaptable”[13].

A MODEL-BASED FRAMEWORK fOR PERSONALIZED LEARNING IN PRODUCTION-ORIENTED E-LEARNING ENVIRONMENT

A model-based framework for supporting of personalized learning in a production-oriented e-learning environment is presented on Figure 1. It integrates various entities that take part in learner-adapted production of this environment. The architecture of this framework consists of the following components: success, learner, product, process and evaluation models. The overriding top-priority success model defines the optimization criterion of the productive e-learning environment and makes some of the other components the primary driver for framework integration [4]. In our case, the success model of productive e-learning environment work is to “Achieve usability of products of e-learning environment”. It requires learner-centered adaptation of learning resources that are products of teacher work and are represented by work product models. According to the success model, the key goal of the productive e-learning environment is to deliver “fit for characteristics and attributes of a learner” learning resources. This requirement to the production-oriented environment qualifies the learner model as primary driver of learning resources production.

The development of personalized learning resources depends on the learner profile, which has multi-layers structure. The bottom layer represents the learner’s preferences, which determine *how* a man learns with pleasure [5]. The upper layer describes learner background that relates to learner’s experience. The top two layers present the attributes of a learner: learner requirements and goals. In the presented framework, the way of transformation of work product models conforms to the model of the teaching process. The top level of the upper loop involves the generalized conceptual model of the initial work product. The lower loop involves elaboration of the conceptual products models until these are reified to the point that can be transformed to a learning resource suitable for a learner.

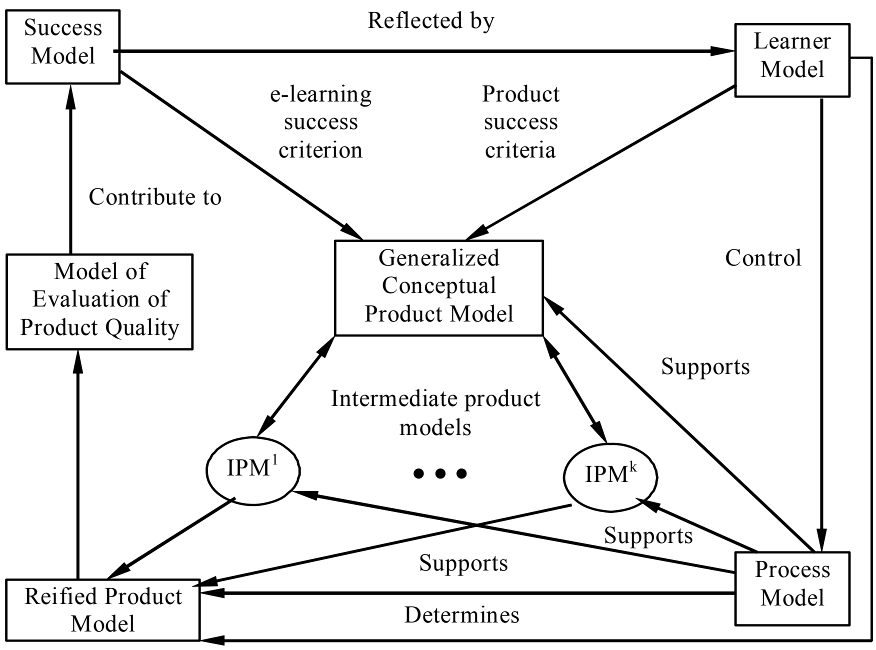

Fig. 1 Framework for personalization of productive e-learning environment

MATHEMATICAL FORMULATIONS AND METHODS

The preferences of learners are estimated on the basis of a mathematical approach that refers to the utility theory [3]. In this case, the learner is considered as a decision-maker (DM). The explicitly expressed preferences of the DM can serve for evaluation of learning resources (object). The main objective of this evaluation is to keep the correlation between the expressed preferences and the DM's utility function. Standard description of the utility function is presented by formula (1). There are a variety of possible final results ($x \in \mathbf{X}$) that are consequence of a DM activity. A utility function U(.) assesses each of these results. The DM judgment is measured quantitatively by the following formula: $U(p) = \sum_i P_i U(x_i), \quad p \text{ is probability distribution } \sum_i P_i = 1$ (1)

We denote with P_i (i =1÷n) subjective or objective probabilities, which reflect the uncertainty of the final results. Strong mathematical formulation of the utility function is the next: Let **X** be the set of alternatives and **P** be a subset of the set of probability distributions over **X**. The DM's preferences over **P** are described by the binary "*preference*" relation ($\succ$) including those over **X (X** $\subseteq$ **P)**. A utility function is any function U(.) for which is fulfilled: $((p \succ q), (p,q) \in \mathbf{P}^2) \Leftrightarrow (\int U(.)dp > \int U(.)dq)$. Thus, the mathematical expectation of the utility U (.) is a quantitative measure concerning the DM preferences about the probability distributions over **X**. In practice the set **P** is a set of finite probability distribution. We suppose that the singleton distributions belong to **P, (X** $\subseteq$ **P).** There are quite different evaluation methods of the utility functions [9, 12] that based prevailing on the “lottery” approach. A "lottery" is every discrete probability distribution over **X**. We mark the lottery “x with probability α and y with probability $(1-\alpha)$” as $<x,y,\alpha>$. There are different systems of axioms (like *Von Neumann and Morgenstern’s axioms*) that give satisfaction conditions of utility existence.

We start with the assumption that any convex combination of elements of **P** belongs to **P**: $(q, p)\in \mathbf{P}^2 \Rightarrow (\alpha q+(1-\alpha)p)\in \mathbf{P}$, for $\forall\alpha \in[0,1]$ [10, 11]. This condition and $(\mathbf{X}\subseteq\mathbf{P})$ determine the utility function over **X** (when this function exists) with the accuracy of an affine transformation. The most used utility assessment approach is comparisons of the kind: $(z \sim <x,y,\alpha>)$, where $(x \succ z \succ y)$, $\alpha\in[0,1]$, $(x,y,z)\in\mathbf{X}^3$. Every comparison of this kind defines a ”learning point” $t=(x,y,z,\alpha)$. With probability $D_1(x,y,z,\alpha)$ the DM assigns the ”learning point” to the set A_u or with $D_2(x,y,z,\alpha)$ to B_u:

$A_u=\{(x, y, z, \alpha)/ (\alpha U(x)+(1-\alpha)U(y))>U(z)\}$, $B_u=\{(x, y, z, \alpha)/ (\alpha U(x)+(1-\alpha)U(y))<=U(z)\}$.

The DM answers ($\succ\Leftrightarrow 1$; $\prec\Leftrightarrow -1$; $\sim\Leftrightarrow 0$) are with probability and subjective uncertainty. The main recurrent stochastic procedure in the proposed approach has the form:

$$c_i^{n+1}=c_i^n+\gamma_n\left[D'(t^{n+1})-\overline{(c^n,\Psi(t^{n+1}))}+\xi^{n+1}\right]\Psi_i(t^{n+1}),\quad \sum_n \gamma_n=+\infty,\ \sum_n \gamma_n^2<+\infty,\ \forall\gamma_n\geq 0. \quad (2)$$

Here $(c^n,\Psi(t))$ denotes scalar product and $D'+\xi$ are the teacher’s answers ($\succ\Leftrightarrow 1$; $\prec\Leftrightarrow -1$; $\sim\Leftrightarrow 0$) were ξ is noise (uncertainty) in the teacher answers with mathematical expectation equal to zero [10, 11]. The scalar product has the form:

$$(c^n,\Psi(t))=\alpha(c^n,\Phi(x))+(1-\alpha)(c^n,\Phi(y))-(c^n,\Phi(z))=\alpha g^n(x)+(1-\alpha)g^n(y)-g^n(z)=G^n(x,y,z,\alpha). \quad (3)$$

The coefficients c_i^n take part in the decomposition of $g^n(x)$ by a chosen family of functions $(\Phi_i(x))$: $g^n(x)=\sum_{i=1}^{N} c_i^n\,\Phi_i(x)$. The line above $\overline{T}=\overline{(c^n,\Psi(t))}$ means that $\overline{T}=1$, if $T>1$, $\overline{T}=-1$ if $T<(-1)$ and $\overline{T}=T$ if $-1<T<1$. It is known that under the procedure (2) conditions specified above the next integral converges to the (min):

$$J_{D'}(G^n(x,y,z,\alpha))=M\left(\int_{D'(t)}^{G^n(t)}(\overline{y}-D'(t))dy\right)=\int\left(\int_{D'(t)}^{G^n(t)}(\overline{y}-D'(t))dy\right)dF\xrightarrow[n]{p.p.}\inf_{s(t)}\int\left(\int_{D'(t)}^{s(t)}(\overline{y}-D'(t))dy\right)dF. \quad (4)$$

Here p.p. denotes “almost sure” and $s(t)$ denotes $s(t)=\alpha s(x)+(1-\alpha)s(y)-s(z)$. After some calculations the following make the convergence clear:

$$\inf_{s(t)}\int\int_{D'(t)}^{s(t)}(\overline{y}-D'(t))dydF \overset{p.p.}{\geq} \overline{\lim_n}\left(\frac{1}{2}\int(\overline{G^n(t)}-D'(t))^2dF\right) \geq 0 \quad (5)$$

Taking in to account the convergence and the structure of the function $G^n(x,y,z,\alpha)$ (3) it is assumed that $g^n(x)$ is approximation of the empirical utility if (n) is sufficiently great.

A USAGE OF THE TECHNIQUE OF LEARNER'S PREFERENCES ESTIMATION

There are shown examples of usage of this technique in the estimation of learner's preferences with regard to the content attributes of learning resources. Its mathematical description is implemented by means of a decision support system developed in the environment of Visual Studio (Visual Basic 6.0). The final calculations and graphics are performed in MATLAB environment.

We apply the developed evaluation tool for representation of learner's preferences to content exposition of learning resources through a function. It concerns the choice of proportion of theoretical presentation to the example-based presentation of knowledge. Figure 2 presents the preference of a learner for content exposition – % theoretical presentation of the whole content presentation.

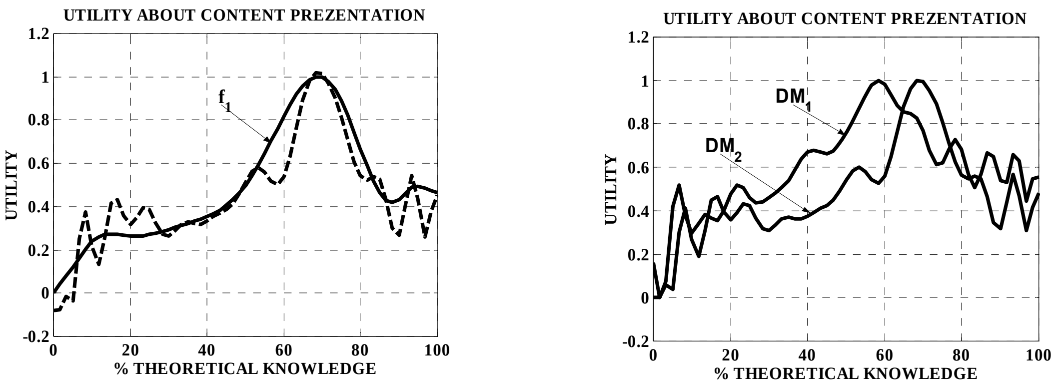

Fig. 2. Learner's preferences to form of content presentation

The seesaw line of the left graphic in the figure recognizes correctly more then 95% of the learner's answers. The stochastic uncertainty makes to see the utility function as a seesaw line. The first evaluation is based on 64 questions (learning points) – utility function $f_1(x)$. It is sufficient only for the first raw approximation. This assessment is fast, since the examination takes about 20 minutes. The utility function $f_1(x)$ clearly reveals the tendency of learner's preference. The right graphic shows estimation of the preferences of two learners (DM_1 and DM_2). It is noticeable that learners have different preferences for the percentage of theoretical knowledge presentation given in learning resources (DM_1 chooses lower level of theoretical presentation than DM_2). Consequently, learners will need altered learning resources, adapted to their preference. Presented graphics are with stochastic uncertainty.

CONCLUSIONS

The presented framework for learner-centered *adaptable e-learning environment* has the followings characteristics: the personalized learning is ensured by a learner model-driven, product-focused process of producing learning resources; learner reference model has layered structure; the learner model controls the production of learning resources; learner-centered adaptation is teaching process capability, this framework supports the optimization of teaching process.

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