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INFORMATION MODEL OF DISTANCE LEARNING SYSTEM IN TERMS OF DATA COMMUNICATION IN HETEROGENEOUS INTERNET NETWORKS

В.А. Крісілов, Ву Нгок Хіу, С.Л. Зіноватна. **Інформаційна модель дистанційної системи навчання в умовах передачі даних в гетерогенних мережах Інтернет.** Через популярність дистанційного навчання в даний час та істотні відмінності програмно-апаратних засобів передачі даних актуальною задачею є варіативність навчальної інформації, що надається студенту. Метою є забезпечення заданих навчальних цілей за рахунок адаптації форматів і типів складових курсу у відповідності з характеристиками передавальної системи в поточному сеансі взаємодії навчального закладу і студента. Запропонована інформаційна модель дистанційної системи навчання, яка описує взаємодію навчального закладу і студента з урахуванням стану технічних засобів передачі та/або прийому вмісту навчального курсу. Отримала подальший розвиток фреймова модель предметної області як структури навчального курсу за рахунок введення додаткових слотів. Описані моделі дозволяють ввести формальні правила специфікації переданої інформації, керуючи часом і якістю передачі за рахунок регулювання обсягу та формату переданої інформації, з досягненням поставлених навчальних цілей.
Ключові слова: інформаційна технологія, дистанційне навчання, навчальний курс, модель

V. Krissilov, Ngoc Vu Huy, S. Zinovatna. **Information model of distance learning system in terms of data communication in heterogeneous Internet networks.** Due to current popularity of distance learning and significant differences in software and hardware data transmission means, the actual problem is the variability of training information provided to a student. The aim is ensuring specified learning objectives by adapting types and formats of the course components in accordance with the characteristics of the transmitting system in the current interaction session between an educational institution and a student. The information model of distance learning system, which describes interaction between the educational institution and the student taking into account the state of technical means of transmitting and/or receiving contents of a learning course, was proposed. Frame-based domain model as the structure of a learning course was further developed by introducing additional slots. The described models allow introducing formal specification rules for transmitted information, controlling time and quality of transmission by regulating the amount and format of information to be transmitted, with the achievement of the set learning objectives.
Keywords: information technology, distance learning, learning course, model

Introduction. Nowadays in order to build a successful career each person must follow the concept of LLL (Long-Life Learning). This is due to the fact that in terms of rapidly developing technologies in all fields of human activity, acquisition of new knowledge is an essential condition for achieving positive results in the work.

Learning with compulsory attendance in the classrooms of educational institutions (EI) is not acceptable for everyone. Due to the development of information technologies (IT), every modern person has a device (computer, tablet, smartphone) with Internet access, and therefore can interact with the EI in order to master the learning courses of various directions that are developed and provided by organizations, located at a significant distance from the place of residence or location of persons who wish to receive education (hereinafter – students). At the same time, appropriate IT should be provided at all stages of interaction between the EI and the student: development of a learning course (LC) in the form of a set of different components; transfer of educational information to target user; reproduction of such content, taking into account the limitations imposed by technical means of the EI and the student.

Obviously, distance learning (DL) is beneficial for both sides of this process. Students can use this form of learning to obtain a full-scale education with a diploma, to improve the level of qualification, and to acquire certificates that can later be counted as separate disciplines. On the part of the EI,

there is the possibility of additional earnings by attracting students who can not study in-person, and reducing costs, for example, by reducing the cost of travel for lecturers conducting exams for off-campus students and evaluating activities at remote branches of the EI [1].

Training systems can have a different organization: from reference books and training information storages to smart labs [2] and virtual universities.

Various DL models are described: a consulting model, a correspondence model, a controlled self-learning model, a network learning model, and others [3].

Various classes of systems for providing DL are considered, in particular MOOC (Massive Open Online Courses), LMS (Learning Management System), LCMS (Learning Content Management System) [4].

MOOC is a type of educational Internet course that assumes mass participation and free access. Generally a typical training course is represented by video lectures with subtitles, homework, text notes of lectures, tests and final exams. For example, Khan Academy – a non-commercial educational organization that offers practical exercises, training videos and a personalized training panel, provides access to free lectures in mathematics, history, healthcare, finance, physics, chemistry, biology, astronomy, economics and others [5]; Coursera is a platform that offers more than 2000 educational courses, has 149 partners and unites more than 25 million students from all over the world [6]; edX is a non-commercial on-line education project, offering free access to courses developed by the world's leading universities [7]; Linda.com is an educational company that provides more than 6,000 courses in business, technology and creative skills, conducted by industry specialists [8].

LMS includes tools for organizing and monitoring the use of computer courses and trainings, as well as for learning process administration in general. For example among such systems are Moodle, Blackboard, SAKAI.

LCMS, opposed to LMS, focuses on the tasks of managing the content of curricula and is aimed at content developers, specialists in methodological layout of courses and learning projects managers. Product of LCMS – Lotus Workplace Collaborative Learning – acts as an example.

The evolution of distance learning systems (DLS) shows that the actual task is to adjust the content of the course according to individual capabilities and/or needs of a student. This problem can be solved in different directions.

In [9] two main technologies in adaptive hypermedia are identified: adaptive navigation support and adaptive presentation. The first technology provides support by creating invisible or visible orientation references, as well as navigating the student in hyperspace. The second technology works on the basis of certain user model. The goal of adaptive presentation technology is to adapt the content of hypermedia pages to the knowledge of user and other information stored in the user model. In the system with adaptive representation the pages are not static, but adaptively generated or sectioned for each user [10].

Adaptivity can be expressed as formation of a learning style, based on the student's behavior [11]. In [12] it was suggested to store the characteristics of the learning style both in description of the student and in description of the object of study, and to perform adaptation of the course content based of this information. In [13] a technique for individualizing the presentation of learning and test material was described, which requires the advanced model of the course and knowledge base that should contain information about the learning and testing process.

Thus, the analysis of interaction between EI and a student should form the basis of information and communication technology (ICT) for the implementation of DLS, and in particular for the formalization of rules of training information formation.

However, in addition to the methodical aspect of training course adaptation, there is also a technical aspect.

Possibilities of receiving and/or transferring remote information can differ both for different EI and for students. In reality of modern Ukraine the accessibility of high-speed Internet throughout the country is still limited. In addition, during communication between EI and a student, a heterogeneous network that connects personal computers and other devices with different operating systems or data transfer protocols is used. The term "heterogeneous networks" is also used in wireless computer net-

works, where different connection technologies are used. For example, a computer network that provides access through a wireless local area network and is able to provide access by switching to cellular communication is also called a heterogeneous network [14].

Therefore, the actual task is the formation of the material to be presented in order to ensure its high-quality reproduction, taking into account the software and hardware used in the learning process, due to dynamic analysis of characteristics of these tools.

The availability of training in conditions of weak connectivity between EI and a student can be improved by providing variability of material presentation, delivering the same educational material in various forms of different structure, format, memory size.

For example, you can give the student a lecture in the form of a video file, a text document, a presentation, etc. Each of these types of representation differs in size in bytes (by times and even by orders).

Thus, it is required to correlate the contents of the transmitted information with the technical capabilities of the distance learning process, adjusting the format and size of the data transmitted during the interaction between EI and a student.

At the same time, the possibilities and limitations of software and hardware should be taken into account, both from the EI and from the student side. Three main components of the general adaptability of the learning system are singled out: functional adaptability; structural adaptability; adaptability of the interface [15]. Adaptation of the contents of educational material according to technical possibilities of the distance learning process can be attributed to the second class – structural adaptability.

The aim of this work is to provide the set learning goals by adapting types and formats of the course components in accordance with the characteristics of the transmitting system in the current interaction session between an educational institution and a student.

Materials and methods. Information model of the distance learning system in terms of data communication in heterogeneous Internet networks

At the upper level three components of DL should be considered:

$$<U, TW, s>,$$

where U – EI that provides DL;

TW – soft hardware for providing the learning process (means of student and EI interaction, communication channel capacity, technical capabilities of devices for transmitting and receiving information);

s – student receiving education distantly.

In this case the transfer of information can be performed not necessarily directly from U to s. For example, methods for delegating tasks of the broadcast server to members outside the EI territory are considered: to specialized broadcast centers, the outermost unit, decentralized broadcasting based on peer-to-peer networks [1].

DLS of an educational institution U in general terms can be described as a tuple

$$<DU, S, DS>,$$

where DU – multitude of courses provided by U to students;

S – multitude of registered students, $s \in S$;

$DS = \left\{ ds_k \middle| ds_k = <d_i, s_j, dt1, dt2, st_{ij}>, k = 1...n \right\}$ – multitude of courses accessible to a specific

student, where $d_i \in DU$ – accessible course, $s_j \in S$ – student, $dt1$ – date the course was opened for access, $dt2$ – course closing date, st_{ij} – statistics on the d_i course passage by a s_j student.

This presentation describing the interaction between EI and students ensures the subsequent formalization of rules for the formation of training information as part of the ICT distance learning.

From the point of technical capabilities of means of obtaining the contents of the LC student s_j can be presented as follows:

$$<tc, tg, ts>,$$

where $tc \in TC$ – type of connection available to a student, can be marked as fixed, if a student is able to use only this type of connection, TC – multitude of available connection types options, typical connection options can be WAP, GPRS, modem, satellite;

$tg \in TG$ – type of device using which a student can access information and can be marked as fixed, if a student is able to use only this type of device, TG – multitude of available device options, for example, typical types of devices are a desktop computer, laptop, tablet, smartphone;

ts – type of student from the viewpoint of learning rights, for example, a correspondence department student, a postgraduate education institute student or a person who wants to obtain additional knowledge in the area of personal interest.

Obviously the contents of the TG and TC multitudes will change with time since new types of connections and devices can appear and outdated elements of multitudes will be deleted.

The general scheme of the DLS organization involves the transfer of individual elements of the ci_{ij} training information of the course $d_i \in DS$, $ci_{ij}=f(ts)$, to the student s_j so that the student studies the required volume of the training material, taking into account technical limitations (see Figure), where V_U is the maximum amount of data that the EI can transmit to a student within given time t; V_S – the maximum amount of data a student can receive within t, using the available technical means, $Vs=f(tc, tg)$; $V=\min(V_U, V_S)$ – the maximum amount of data that can be transmitted in the current communication session between the EI and a student, while V_U and V_S can change over time.

Currently in view of actuality of providing DL there are various formal descriptions of the learning process. Thus, the formalized information model of the LC is proposed, in which the F_g frames representing the objectives of the LC are stated at the first level of the presentation, the F_c frames corresponding to the concepts are defined at the second level, the F_m frames representing the learning materials associated with the individual concepts are located at the third level [16]. Each F_m frame is described by slots distributed in the following sections:

– general information: title, short description, creation date, version;
– semantics: concept type ("main", "relational", "preparatory"); topic (course subsection) tm;
– pedagogical attributes.

Material that facilitates achieving a set learning goal can be given to students with different tc and tg, each in its own form.

It is suggested to expand the general information section in the F_m frame model by adding npp and ta slots to it, where npp is a content item number of the transmitted information in the order of the exposition, and ta are attributes describing properties of the training module in terms of software and hardware.

The slot ta is a tuple $< tct, sct, pr >$, where tct is a type of a content element of transmitted information (video, graphics, text, etc.); sct – size of a content element of transmitted information in bytes; pr – priority of using this content element of transmitted information with equal size of sct with other elements.

Based on the analysis of the current state TW of the student s_j (V_S) and the DLS of the EI (V_U) the content of the training material, which is provided to the student when the training module from the d_i course is requested during the current session, is identified. The formalized specification of the components of the ci_{ij} course provides the required quality of training, reducing the time t to reach a given volume of V_{const} training objectives and / or increasing the V achieved teaching goals for a given t_{const} time.
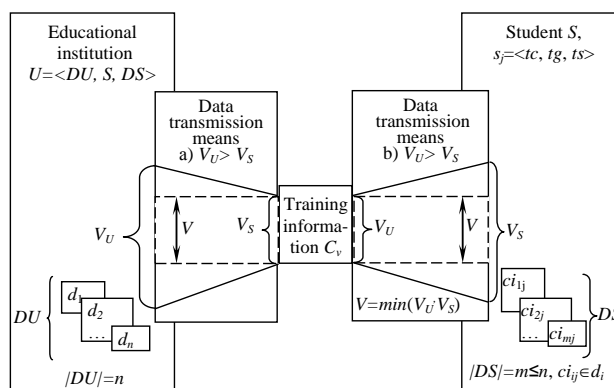
General scheme of DLS organization taking into account technical means of interaction between EI and student

Rules of course contents formation for a student. Let us present a course d as the following hierarchy: Course → Topic → Course content element ci, $ci \in CI$, where CI is the multitude of all course content elements.

$$ci = <idct, d, tm, tct, ct, npp, vr, sct, pr>,$$

where $idct$ – identifier of course content element (CCE);

d – course, to which the CCE element belongs;

tm – topic, to which the CCE element belongs;

tct – type of CCE element (video, graphics, text, etc.);

ct – content of CCE element itself;

vr – compulsory nature of the statement, equals 1 if the CCE element is mandatory for viewing, and equals 0 in the other case;

sct – CCE element size in bytes;

pr – statement priority of CCE.

Let us define the following functions.

Function Fps determines bandwidth U–S

$$Fps = f(tc_{cur}, tg_{cur}, nst),$$

where tc_{cur} – current connection type of a student, equals tc, if this component is marked as fixed for student s_j;

tg_{cur} – current device type of a student, equals tg, if this component is marked as fixed for student s_j;

nst – number of students currently working online in the distance learning system.

The result of Fps function is the qm value – maximum amount of data that a student can receive at a given time. After receiving qm the CCE identifier function ci_{ij} should be applied

$$Fid = f(ds, tms, npsp, qm),$$

which chooses $idct$ according to the following rules (where $ds, tms, npps$ – course, topic and CCE reference number, chosen s_j in the given interaction session with the EI correspondingly):

– multitude $CI1 \subseteq CI$ is formed according to the following rule: if for $ci_k \in CI$ $d_k = ds$, $tm_k = tms$, $npp_k = npp$, then ci_k is included in $CI1$;

– multitude $CI2 \subseteq CI1$ is formed according to the following rule: if for $ci_k \in CI1$ $sct_k \leq qm$, then ci_k is included in $CI2$;

– multitude $CI3 \subseteq CI2$ is formed according to the following rule: if for $ci_k \in CI2$ $sct_k = sctmax$, where $CI2, k = \overline{1, CI2}$, then ci_k is included in $CI3$;

– if $|CI3| > 1$, then that $idct$ that has the maximum value of pr is chosen out of $CI3$.

If $|CI3| = 0$ and $fvr = 1$, where $fvr = f(ds, tms, npps)$ returns vr of CCE with $d = ds$, $tm = tms$, $npp = npps$, then the condition of the second rule changes as follows: a multitude $CI2 \subseteq CI1$ is formed, that includes CCEs having $sct = sctmin$, where $CI1, k = \overline{1, CI1}$. The third rule is ignored.

Description of the experiment. In order to assess the presentation quality of the learning course with firmware that is used to receive and/or transmit data, an experiment was conducted in the form of an online session based on BigBlueButton [17] and Moodle [18, 19] on a server with the following characteristics: Ubuntu 14.04.5 LTS 64 bit, 4GB of RAM, 64KiB L1 cache, 4MiB L2 cache, Intel(R) Core(TM) i5 CPU 650 @ 3.20GHz, open ports 80, 1935, 9123. Five students were connected with PCs and laptops (headphones, a microphone and a webcam) with different characteristics of the computers they used. During the session the quality of audio, video and user-friendliness was assessed. With such a relatively small number of DLS users some participants had problems with each of the evaluated components: slowing image output during broadcast, image falling behind sound, inconvenience when working with a small display, distortion of sound.

Obviously, such weaknesses should be eliminated. At the same time it is necessary to take into account that the state of technical means while transmitting and receiving information can vary from session to session. Based on the data obtained using the developed tools for automated characterization of firmware in the current session for the EI and each student-participant and specification of the

LC components transmitted in the conditions of a particular session, the characteristics of providing information have been improved: image falling behind sound and image output delay was eliminated.

Conclusions. The solution of the adaptivity problem in DLS is analyzed. The formal description of the interaction between the EI and the student is performed, which enabled the decomposition of the task of specifying the contents of the transmitted information between the EI and the student. For the first time an information model of data transmission in heterogeneous Internet networks for DLS is developed, in which the student is presented in terms of technical capabilities of means for obtaining training information, the components that affect the formation of transmitted information are introduced in the form of sets of elements, typical elements of these sets are shown. The frame model of application domain as the structure of the LC was further developed due to introducing additional slots. The proposed models make it possible to implement formal rules for determining the type and format of transmitted information according to the characteristics of the current communication session while ensuring the achievement of the set learning goals.

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