

## **An innovative Internet database system for teaching assignment management and quality assurance at the Technical University of Łódź**

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**ABSTRACT:** A brief description of an Internet database system for teaching and research information management is presented in this article. The system was developed and deployed successfully at the Faculty of Electrical, Electronic, Computer and Control Engineering, Technical University of Łódź, Łódź, Poland. It facilitates the most important activities of the community of 4,500 students and 450 Faculty staff members. The core elements of the system are an Internet database and a number of specialised computer programs (terminals) with diverse functionality (teaching assignment, marking, student portal, course evaluation, cost analysis, etc). These terminals are used to enter, edit and retrieve data related to teaching, research and other activities at the Faculty. It facilitates funds allocation, cost analysis and teaching quality assurance. Data security is achieved by using smart cards, which provide storage of personal secret keys for data encryption and electronic signature generation, while communicating on-line with the database. The system has been introduced to all the Faculties of the Technical University of Łódź (20,000 students and 3,000 staff members).

### INTRODUCTION

Over the recent years, a paradigm shift is observed from the university as a place of intellectual challenge to the university as a complex enterprise - competitive, cost-effective, agile and responsive to the changing needs and expectations of the society. Universities have to provide diverse academic services to a large number of people who are involved in a variety of activities (teaching/learning, curricula development, research), as well as non-academic campus services and facilities. Operation control of such enterprise requires efficient management of extensive organisational knowledge and information. Nowadays, this would be unthinkable without a database system or a network of local databases (more or less) seamlessly connected to each other. Much of the information stored includes user individual data, such as personal information, marks acquired by students or staff salaries. Such sensitive information should not be disclosed to unauthorised persons. Thus, users transfer the information to the database and read through secure communication channels. To make the channel secure, the user must be identified by a unique ID code used, e.g. to encrypt the information and/or attach electronic signature to the data chunks [1][2]. These days, typically authorisation is carried out with the use of a plastic smart card, which provides suitable storage and cryptographic support.

This article provides information about the architecture, functions and implementation issues of the Students' Electronic Card system developed at Faculty of Electrical, Electronic, Computer and Control Engineering of the Technical University of Łódź (EECCE-TUL), Łódź, Poland. The system is an extensively verified, working example of a vital, widespread and still growing application of secure Internet database systems designed for the support of management of a very complex enterprise - a university.

### PROJECT MOTIVATION AND BACKGROUND

The need to introduce electronic documentation was already well recognised at the Faculty in the mid nineties. The four-fold increase of the number of students in just a few years (to about 4,500 students, which made the EECCE the largest TUL faculty), posed many organisational problems for academic and administrative staff. The first attempt to aid the management of teaching information at the Faculty was the idea of issuing an *electronic academic record book* to each student in the form of a plastic card with her/his photo for visual identification, and a digital memory of capacity sufficient to store all necessary data for the duration of the study period. At the beginning of each semester, the card would be loaded at the dean's office with a list of courses to be completed by a student, and at the end of the semester, corresponding marks would be entered by teachers. This concept was first considered in 1996-98 and was hoped to break a data transfer bottleneck happening at the turn of any two semesters. This card was to be carried in a pocket of the paper *academic record book* (which cannot be eliminated due to Polish national regulations). Teachers were to write in the marks both to the paper book and to the card memory, the latter with the use of a card reader connected to a computer. Prototype card readers and software modules were designed, developed and used for tests that

confirmed the technical feasibility of the system. After assessment of the investment, material and exploitation costs of the solution, accounting for the size of the Faculty (4,500 students and more than 450 faculty and administrative/technical staff) the basic assumptions concerning the system concept were modified [3]. A decision was made that marks will be stored in a common Internet database accessed by teachers and administrative staff, and microprocessor cards would be issued to them only. Main function of the card was the storage of user identification data and private keys used for the encryption and digital signature of the data exchanged between the Internet database and the system terminals [4]. Based on this concept, a complex faculty information processing system has been developed and expanded, which now involves also students (with no authorisation to write the crucial data into the database, yet). It is envisaged that wide introduction of electronic student ID cards will allow granting the students the right to enter various data, make payments, etc, while maintaining data security.

## SYSTEM ARCHITECTURE

The architecture of the system, with the teaching information flow, is illustrated in Figure 1. All the information collected in the Faculty is stored in a single Internet database. The Oracle 10g database management system was chosen in the TUL EECCE computer *Students' Electronic Card* (SEC) system design [5]. The SEC system users save the information and retrieve it from the database by means of terminals - computers equipped with a card reader and specialised software. In the case of the management of information related to teaching, as illustrated in Figure 1, there are 4 types of terminal - study programs terminal, dean's office terminal, teaching unit (i.e. department or institute) terminal and teacher terminal. Other terminal types are used to collect and/or process information related to research, cost analysis of the Faculty activities, card management, etc, and these will be discussed later. A student portal, which is in fact a Web application, is also integrated with the system as shown in Figure 1. Two secure interfaces/channels that synchronise two separate data sets have been developed. A set of data, which is frequently updated (e.g. lists of obligatory and elective courses, partial and final marks, dean's decisions, financial data) is fetched on-line directly from the central Oracle database.

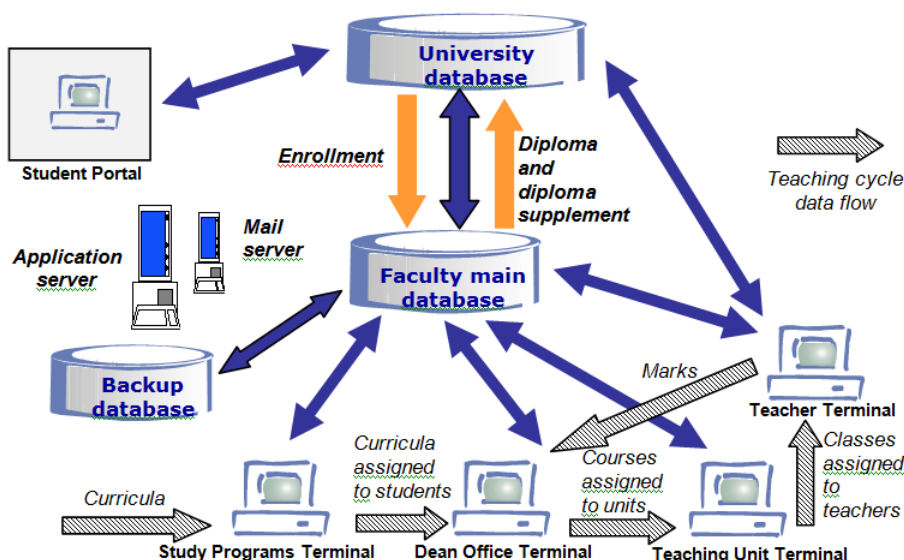


Figure 1: SEC system architecture with an example of teaching-related flow of information.

The data undergoing occasional modifications (e.g. student and teacher personal data, curricula, contact details, etc) are buffered in a Postgres database and synchronised twice a day to the main Oracle system. Students can browse their personal data (marks, enrolment to consecutive semesters, fees due and paid, etc) after logging in to a password-protected portal. An important function of the student portal is in teaching quality assurance by collecting students' answers to questionnaires on courses, teachers and organisation of studies. Thanks to the portal integrated with the information management system, more than 80% of the students give feedback on the important aspects of the study to the Faculty. In the future, once electronic student ID cards are issued also to the students, the functionality of the student portal will be extended to, e.g. electronic submission of study-related documents to the dean office.

## DATA SECURITY

The data protection means built into the SEC information management system include: limited access to data (user authorisation required, many user types defined with access right restrictions), protection of the data content from unauthorised reading (encryption), measures of checking data integrity and authenticity (digital signature). The basic tool of information protection is the microprocessor card. Hybrid microprocessor cards Gemplus MPCOS-EMV R5 8,000 (8kB) with Mifare contactless module (1kB) are currently used in the system [6][7]. They are used to store: a) user identification data; b) cryptographic keys; c) electronic purse files; d) access control information. Access to the

smart card is protected by a secret personal identification number (PIN). Data written in to the database are encrypted [1] and signed digitally [2]. The use of electronic cards introduces very high data security level, which practically make data eavesdropping or modification by unauthorised users impossible. No security related incidents have been observed since the deployment of the system. On top of the above-described numerous security means, the standard firewall technique of terminal communication with the database is used, the security mechanisms available with the Oracle DBMS are utilised, and terminal communication with cards is kept secret.

A system terminal is a standard PC computer run under MS Windows operating system, equipped with a card reader and dedicated software. An example of a card reader connected to a notebook computer through a serial USB port is shown in Figure 2. Software for the terminals was written in Object Pascal and C++ languages using Borland Delphi and Borland C++ Builder development environments respectively. The student portal (PS) is encoded as PHP language scripts running on an Apache server. The electronic signature procedures are implemented by means of C++ and Object Pascal routines developed at the Faculty. The routines encode SHA-1 [8] and DSA [9] algorithms with the use of modular arithmetic [10]. Data encryption software modules use the TDEA (triple DES) algorithm [11].

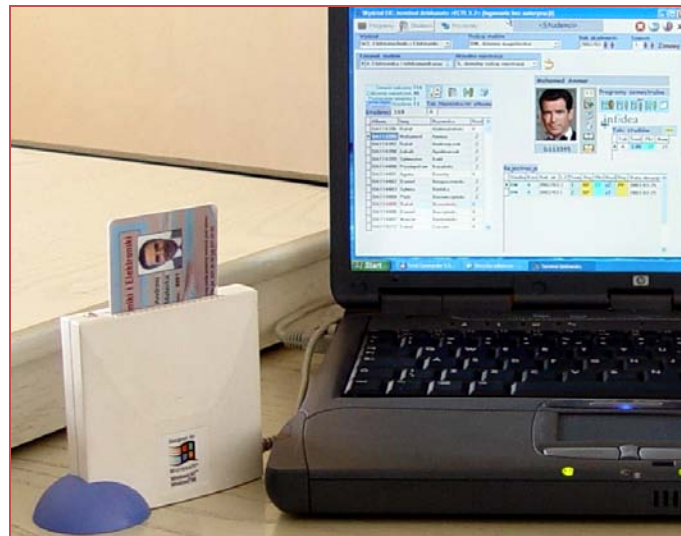


Figure 2: Sample card reader (bottom left) connected to a PC terminal (dean’s office terminal window).

Four layers of access protection to the card data files, implemented in the TUL EECCE information management system, are illustrated in Figure 3.

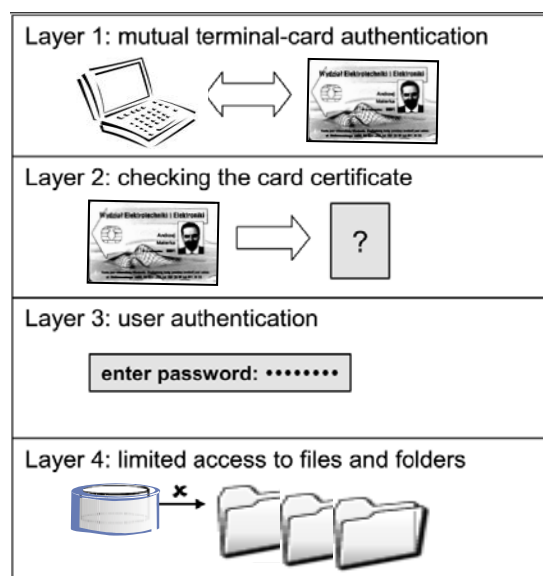


Figure 3: Layers of access protection to data stored in the card memory.

There are six user categories, each attributed different rights to access the card data files and database records - teachers, dean’s office administrative staff, dean and dean deputies, teaching unit terminal operators, system administrators and students. A special printer is used to print the Faculty and user-related information on both sides of the white plastic cards as they come from the vendor. A card issuing terminal (TWK) is used for card personalisation. It comprises

electronic encoding of data structure in the card memory, system information, user personal data, digital certificate of the card, prior to graphic personalisation.

## TEACHING MANAGEMENT SUPPORT

The single-Internet-database architecture (Figure 1), with terminals located in the Faculty teaching units (institutes and departments), allows for on-line assignment of teaching load and continuous verification of the assignment consistency (e.g. versus study programs) throughout the whole Faculty. For example, information about the actual number of students, who have taken any subject class, are easily available to the dean or a deputy dean once teachers make proper choices from a list of student names generated by the system. After the pilot studies and initial tests, the system was put into operation in 2002, to include year 1 students, studying under the European Credit Transfer System (ECTS) [11]. Year by year, newly enrolled students' records were added to the database. Since 2006, data of all the Faculty students have been stored and processed by the system. The benefits of using the system, in terms of speed of information collection and data consistency, as well as in availability of information which would otherwise not be possible to extract, are very clearly seen now. Positive evaluation made the Faculty decide to expand the system functionality to cover other strategic areas of its activity, beyond course assignment and marking.

The database in the Faculty system is a rich source of information, essential to various aspects of Faculty activity. Often, there is a need to extract this information in a non-standard form, e.g. for statistical purposes. A reporting module was designed and written for this purpose. Various information selection criteria can be selected from a list corresponding to the information fields stored in the database. The module dynamically generates an SQL query, which is sent to the base. The result (a report generated in response) is displayed on the computer screen and can be saved as an HTML or Excel file. This unique flexibility in report generation is a very useful feature, e.g. to satisfy the needs of statistical reports preparation requested by the Ministry for Science and Higher Education.

## SUPPORT FOR TEACHING QUALITY ASSURANCE

Students are key partners and crucial participants in a teaching quality assurance system. Student representatives sit on all University committees that deal with teaching quality: Faculty boards, their sub-committees and the Senate. The procedures introduced at the Technical University of Łódź help communicate teaching content in ways that will address the expectations of students better and indirectly also of employers. One of the devices is the Course Evaluation Survey Questionnaire. Students are asked to fill the questionnaire using the Student Portal. The survey embraces about fifteen aspects of the course evaluation: organisation, understanding the content, teaching approach, attitude of the teacher, teacher availability for students, etc. In order to avoid *questionnaire fatigue*, courses are evaluated on a rolling basis. Where courses are relatively well established and students are mostly satisfied, it may be appropriate to use the questionnaire for a fourth of the courses every year, so that each is reviewed every four years.

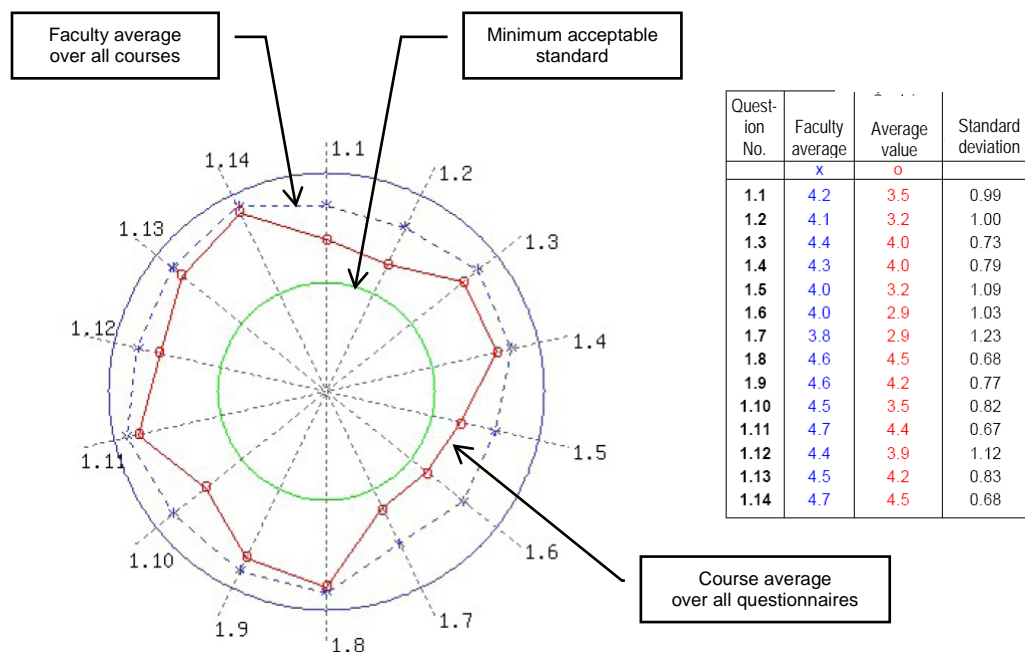


Figure 4: Example course evaluation circular plot.

## RESEARCH ACTIVITY TERMINAL

The architecture of Figure 1 was also adopted for a system collecting and processing information related to the Faculty's research activity. A new research (TBN - Terminal Badań Naukowych in Polish) terminal has been designed

and implemented for this purpose, running the *Skryba* program. Depending on the user's privileges (read-out from the user card), the terminal changes its interface to allow information to be written to the database (for officers representing the Faculty units, see Figure 5) or reading out the information only (for dean office workers). The TBN terminal allows collection of detailed information about research projects/grants carried out in the institutes and departments, as well as on publications (bibliography data).

Each form of research achievement is allocated a number of points, which are used to evaluate research activity in the Faculty units. The points scored by a Faculty unit (institute or department) in a year are the basis for research funds allocation in the following year. Reports are generated, to make e.g. a list of publications for each unit, and the whole Faculty for documentation required by the Ministry for Science and Higher Education and the University Library for staff assessment, planning and other needs. A staff portal (based on an idea similar to the above described student portal) is under development now to provide individual staff members with an Internet access to their research record data. Another direction of the system expansion is in the area of card-based access control, e.g. to student laboratories. Both contact and contactless cards are considered in an in-progress Faculty project. Once electronic student ID cards are introduced within the University, they will be integrated with the existing system.

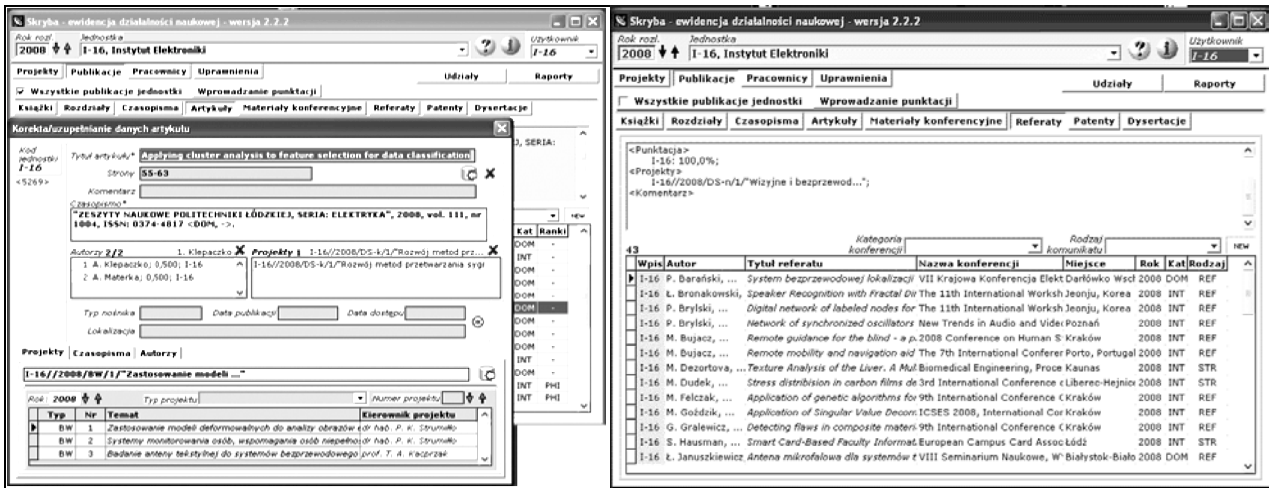


Figure 5: Sample windows for entering information on journal papers of TBN terminal (module *Skryba*).

## COST ANALYSIS

One of the essential factors of Faculty management is identification of various sources of costs of running the teaching process. The cost components (staff salaries, cost of overtime hours) should be evaluated and compared with the Faculty income (yearly funds granted by ministry, student fees, etc). One can then compute average costs of running specific courses or form of studies, e.g. evening courses, part time studies, for cost efficiency. Such data is the basis for strategic analyses, e.g. in the area of employment structure that matches the teaching quality criteria and gives maximum cost efficiency at the same time. To allow cost analysis in the SEC system, the system has been augmented with two terminals staff terminal (TK with the *Kadry* program) and finance terminal (TF with the *Krezus* program), and the functionality of the teaching unit terminal (TJD, using the *Ekstazjusz* program) has been significantly enhanced. The terminals are used to collect and process information for the cost analysis task, as illustrated in Figure 6.

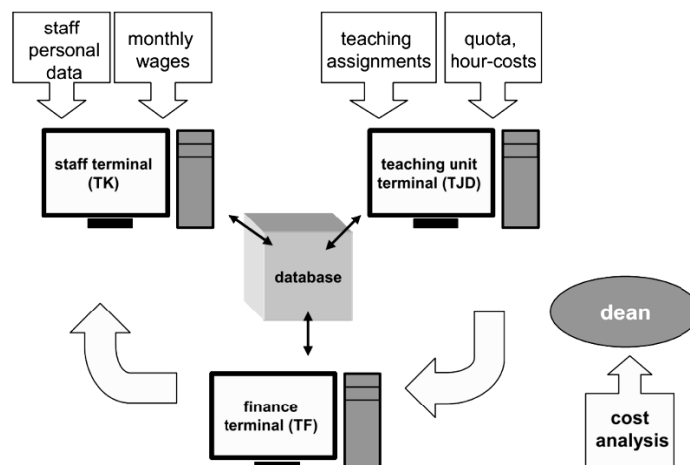


Figure 6: Diagram of information flow for cost analysis.

## DESIGN, DEVELOPMENT AND EXPANSION

The prototype system was designed and built in 1996-1998 by a 7-person team of experienced electronic engineers/computer programmers. Four of them had had previous 2-4 years teaching and research work experience at foreign universities (USA, Australia, Japan, Great Britain), which helped to introduce the credit point study system at the Faculty. The functionality of the prototype information management system was discussed in detail with the Faculty dean officers - the prospective users. System design and deployment required solution of many complex engineering problems (functionality specification, database design, software development user interfaces, secure card reader communication, algorithms for data encryption and digital signature) and, even more difficult, many logistic problems related to organisation of the work of different groups of users (teachers, administration, students).

One of the major problems at that time was extraction of tacit organisational knowledge of many individual staff members and its conversion into explicit formal procedures appropriate for a computer implementation. For the 10 years of the system's operation, its functionality has been evaluated continuously (by a formal team of nominated users), and updated and upgraded by a team of a few programmers. One of the recent projects in this area is Electronic Education Connectivity Solution, aimed at providing support to Bologna processed-governed student mobility between European universities, funded in 2009-2011 from Seventh Framework European program resources [13].

Since the very beginning of the system development, and especially after introduction of the ECTS study system at TUL in 2002, it was evident that there was as a need for data exchange between the University central database and Faculty local systems. Since both the SEC system and the central University system keep evolving, updates of the data exchange protocols are necessary and result in additional burden and cost. This gives incentive to integrate both systems and (probably as the major benefit) gradually introduce mature solutions implemented in SEC to all the faculties of the Technical University of Łódź (20,000 students and 3,000 staff members). The integration process is underway but it will take several years due to the number of problems that have to be solved *in-vivo* such as data migration, introduction of common procedures, functionality merging, staff training, etc.

## SUMMARY AND CONCLUSIONS

The core elements of the SEC information management system at TUL EECCE Faculty are an Internet database, a number of software terminals with various functionality and microprocessor cards for the storage of users' personal information and private keys for data encryption and digital signatures. The system ensures high security level necessary for storing of personal information. The database - as a single source of information - allows fast access and reduces the very high costs of verification and processing of the data collected in paper form. The introduction of the system contributed much to the quality of the Faculty work. Some vital decision-support analyses were not possible at all before, e.g. detailed cost evaluation of average teaching hour, say, at evening courses in satellite TUL campuses.

Implementation of a campus card system is a complex task, not only from the technical, but mainly organisational point of view. It was found essential that users of the university systems were involved in the process of setting system specification, testing and evaluation of new hardware and software modules. It would be very difficult for an independent external software company, with little experience in the management of teaching and research organisation, to develop a system tailored to the needs of the Faculty. The authors hope that this article will help sharing experience by universities implementing such systems at their campuses. Since design, development and implementation are very complex tasks, it is believed that such information exchange is necessary. There is strong Europe-wide commitment to this approach, with emphasis on developing standards for information exchange, especially in view of the huge diversity in tradition of European academic institutions and rapidly growing number of students on international exchange [14].

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