ORGANON — The Web Tutor for Basic Logic Courses

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Abstract

We would like to introduce the web tutor ORGANON, which aims to support basic logic courses at the University of West Bohemia in Pilsen (Czech Republic). The application was designed to fulfill two requirements. Firstly, it should help students during their study to practice exercises on their own (providing permanent control during students' practicing exercises as well as answering students' questions immediately as they arise). Secondly, it should reduce teachers' burden (diminishing the amount of consultations as well as administrating students' homework including correcting and grading). The tutor is available at `http://kfi.zcu.cz/lide/dostalova/organon`.

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1 Motivation of the Project

Basic logic courses are obligatory within different fields of study in the Czech Republic. Usually they are one term long, they cover propositional and predicate logic on just an elementary level, and they are designed for a great number of students; several hundreds of students is not exceptional. Successful completion of these courses usually requires a substantial portion of individual work, because it consists of solving logic exercises in order to obtain skills in handling formalism. Though individual solving of exercises is the most effective way how to teach (modern) logic and to make students familiar with logical notation, relevant literature is completely missing. There are no exercise books with example solutions or with an answer key. Therefore, teachers have to create a lot of exercises each year, themselves; then they have to correct and grade them; and finally they have to consult the students about the results. Because of the mass character of basic logic courses, such a task is hard to manage. The problems that students usually deal with and want to consult a teacher for most of all, are of the kind that can be easily solved or answered in an automatic way. So appropriate computer-based assistance may solve the problem.

At first we looked for existing software, which would be able to support these courses. There is a wide range of various didactic software for logic (LPL-software, Socrates, Plato) as well as a lot of web tutors (Apros, Pandora). They provide elaborated didactics, but they are monothematic as they have only a fixed and a limited amount of exercises. Furthermore they ignore completely the administration of teaching (correcting, grading and storing of achieved results). On the contrary, systems

designed to fulfill the management requirements of teaching (for example e-learning systems) do not reflect special needs of logic as a discipline. They were designed mostly for disciplines of an encyclopedic character. This is inadequate for logic exercises, which are mostly computational; not to mention the problems concerning the use of logic notation. The web tutor ORGANON was developed to accommodate both these functions: to handle logic exercises (like specialized software and web tutors for teaching logic) as well as to manage the administration and management of teaching (in the same way as e-learning systems do).

2 Description of the Web Tutor ORGANON

The web tutor ORGANON that was designed to support basic logic courses has two main functions — to support consultations and to manage automatic assessment. The basis of the tutor is formed by *the Database of Exercises*. Upon this database both modules of the tutor — *the Practicing Module* as well as the *Assessment Module* — are built up.

- The Database of Exercises is precisely structured and sufficiently rich — hence it:
  - provides exercises for students' practicing as well as graded homework,
  - allows automatic control of the solution and (especially) grading of the exercises,
  - warrants the individual work as well as the comparability of achieved results.
- The Assessment Module administrates students' homework — it:
  - generates the exercises for the graded homework,
  - facilitates the electronic elaboration as well as the delivery of the homework,
  - manages to correct and grade the homework,
  - stores the achieved results including the record of the exercise, the students' solution, the results of the automatic correcting and the grading,
  - gathers statistical data to provide feedback.
- The Practicing Module helps the students in practicing the exercises — it:
  - shows (step by step) the example solution of the exercise and provides relevant explanations,
  - provides permanent assistance during the students' course, on how to solve the exercise:
    - checking each step of student's solution when finished (automatic),
    - alerting when a mistake appears (automatic) as well as showing the mistake (if required by the student),
    - giving hints for the next step or performing that step directly including relevant explanation and feedback (if required by the student),
  - corrects the student's solution when finished (not during the process of solving) and comments it in the same way as graded homework.

The decision to create a web application, not a software package, was adopted in order to reduce the amount of software claims — all the requirements are server–side. Students need only a computer with internet access and a browser. They do not need to install anything — the only computer literacy required, is to move over the web page and to click the mouse.

The administration of teaching (i.e. the structure of the course, test parameters, evaluation functions, ways of communication etc.) follows the experiences obtained

by using various e-learning systems. Using MOODLE seems to be the most inspiring in this manner. But, ordinary functions of e-learning systems are modified to satisfy the special requirements of logic as a discipline.

First of all it was necessary to create a comfortable user interface to accommodate logical notation. Thanks to the distribution of the Czech keyboard it was impossible to use regular computer notation of logic symbols. Therefore symbols are typed through the "calculator" which forms an inseparable part of the interface. This way of writing symbols is a bit tedious but intuitive — there are no keyboard shortcuts to be remembered. It also prevents conflicts of fonts and charsets.

Further, the web tutor ORGANON includes a database of exercises, which will include regular topics of basic logic courses (propositional logic, predicate logic, syllogistic, arguments, equivalency, formalization, etc.). Such a database is completely missing in our region. The typology of exercises in the database is precisely structured so they can be corrected automatically and used for different courses at various levels or fields of study.

Finally, the greatest advantage of ORGANON against the regular e-learning systems is the fact that beside the usual test–type questions and exercises (like choosing the correct answer among many possibilities, questions with a definite answer, filling in the missing words, and so on), ORGANON is able to handle specific logic exercises with peculiar method of solution. Most of the exercises used during the logic courses are computational. That means that it is necessary to check the whole progress of the solution, and not only the result. Such exercises are accompanied with specific problem solving procedures of ORGANON, that allow automatic checking and grading of student's solutions.

3 The Database of Exercises

The database of exercises was created to fulfill two requirements — richness and the structure. It must be rich enough to warrant individual work for hundreds of students and it must be precisely structured to allow automatic checking and grading as well as to apply didactic approaches. The richness of the database is constituted by the fact that the exercises are generated from patterns by the random substitution. As for the structure, the exercises are sorted into the categories according to the topic, and within the category they are ordered into types according to their difficulty. The typology was designed upon experiences from teaching and in accord with the didactic needs of the courses. Such a precise typology constitutes also the starting point for creating algorithms to solve the exercises and grade them by computer in an automatic way.

The database will cover regular topics of basic logic courses, i.e. propositional logic, predicate logic, formalization, arguments and syllogistics. Each *category* represents a partial subject within the topic — usually a concrete syntactic operation to be practiced. For example, there will be categories of well-formed-formula check, truth-tables, transformations to conjunctive or disjunctive normal forms and propositional deduction calculus in propositional logic, or transformations to prenex normal forms and predicate deduction calculus in predicate logic, and so on.

Each category is organized into the hierarchy of *types*. A type consists of exercises of the same difficulty level. The difficulty of the exercise is usually measured or

expressed in terms of logical laws, which must be inevitably used when solving the exercise. In other words — type is formed by exercises, which have the same method of solution — the same procedures (laws of logic) must be used during the process of solution, e.g., the laws of DeMorgan, the definitions of the logical connectives, and so on. This hierarchy of types allows to assign all the students individual homework of the same complexity (Assessment Module), as well as to proceed from the easiest exercises to the more difficult ones (Practicing Module).

The database is filled up by *patterns*, not by concrete exercises — an exercise is generated from the pattern through random substitution into the pattern. Hence the database is significantly rich:

- In case of exercises using formulas (like transformations to conjunctive and disjunctive normal forms) 96 different exercises with an identical solution method are generated from one pattern by random substitution of literals into the pattern formula, which has three propositional variables. Currently each type is formed by 4 patterns of comparable (if not identical) ways to solve it, hence there are 384 exercises of the same difficulty in one type.
- In case of exercises having the verbal setting (like analyzing arguments or the equivalency check of natural language sentences), the number of exercises generated from one pattern depends on the extent of the source table with the sentence variants. But still there are about 30 exercises generated from one pattern by substituting individual sentences into the pattern of verbal setting — that is about 300 exercises in a type.

Currently the database contains only three categories:

- semantic (truth-value) tables (propositional logic)
- transformation to conjunctive and disjunctive normal form (propositional logic)
- and transformation to prenex normal form (predicate logic)

each of them consisting of 10–20 types. But five other categories (natural deduction; equivalency in predicate logic; formalization in predicate logic; square of opposition as in traditional logic; and syllogisms) are in progress.

In this manner a sufficiently rich and precisely structured database of logic exercises was built up. The independency of graded homework and practicing, is warranted by the fact that the teacher assigns to graded homework other types of exercises than those assigned to practicing, and that it is precluded to transfer exercises between Practicing and Assessment Modules. Structuring the database into the categories and types with respect to the topic, as well as the way and difficulty of solution, admits to change the structure of exercises and homework of the course (in amount as well as in sorts) arbitrarily each term. Furthermore, the same database can be used for courses of a different topic structure and at different levels at once. The database can be also extended adding new types as well as categories of exercises. Finally, the considerable extent of the database warrants individual work of students, though the structure of the database guarantees that all the students solve the exercises of the same complexity.

4 The Assessment Module of the ORGANON

The Assessment Module of the ORGANON was created to manage the whole administration of the individual students' homework including generating exercises, grading delivered homework and storing the achieved results. This homework is designed to force the students to practice regularly during the term and to solve the minimum number of exercises necessary to obtain required skills, i.e. to become familiar with logical notation and elementary syntactic operations. The most effective way to obtain these skills is individual problem solving. The number of exercises need not be large — usually an ordinary student needs to solve independently about five exercises of the specific sort to be able to deal with them (with the exception of deduction calculus, where the number must be at least twice as large). Beside regular homework, the Assessment Module is also able to manage the final exam test of the course, if required by the teacher.

Generating homework from the structured and rich database warrants that all the students are assigned individual homework of comparable if not identical complexity. The precise typology of the exercises allows the automatic correcting and grading of the exercises, which results in faster and more proper assessment eliminating oversight errors, which even the best teacher can never avoid, especially in case of hundreds of students. Automatic storage not only of the achieved results, but also of the whole process of assigning, elaborating and grading the homework, guarantees that it is always possible to check the computer grades in case of doubts.

The grading is based on the automatic solving procedure associated with the sort of the exercise. In case of the test–type question, the process is the same as in regular e-learning systems — it rests in counting points assigned to the answers chosen by the student. In case of computational exercises, there is always an automatic solving procedure associated with them. This procedure allows the application to show the exemplar solution (Practicing Module) as well as to grade the homework (Assessment Module). The resulting grades reflect not only whether the answer is correct or not, but also the whole procedure of solving — it is a proportion of how many mistakes the student has made, and how many stages he has completed successfully.

The Student is allowed to enter his personal account only. No other part of the web tutor outside his personal account (namely the database) is accessible to him. The Assessment Module of the ORGANON forms the interface for the student's elaboration and delivery of homework. The student is allowed to enter and work on homework several times, until he submits the homework or until the deadline has expired. All the work done is saved and can be opened again and changed. The homework is corrected and graded by the application automatically, when sent, so the student may see immediately his results — not only grades but also mistakes and relevant feedback. Exercises of the homework of a concrete student are chosen randomly by the computer from the exercises of the sort defined by the teacher. Thanks to the extent of the database, each student is assigned individual homework, hence the individuality of work is guaranteed. Since the exercises are generated from the same types (exercises having the same solving procedure), the achieved results are directly comparable.

The Teacher is allowed to define the structure of homework, specifying the number of graded homework, the number of exercises in each homework and assigning types of exercises from the database to them. He has access to the whole database, and

may create the structure as well as the extent of the graded homework at will in order to accomplish the goals of his course. Furthermore, he is allowed to see not only the results and the grading of his students, but also the records of the exercises assigned to them, the whole student's procedure of solution and (of course) computer correction and grading of the homework in detail. That means, that in case of doubts it is always possible to control the automatic grading in person. Finally, the application gathers and provides statistical data, like the average success of the students, the relative difficulty of exercises, and so on. Such information may indicate inconsistencies in the structure of the exercises and the necessity of changes in the course of study.

5 Practicing Module of the ORGANON

The interactive didactic Practicing Module of the ORGANON should help the students to practice the exercises before solving the graded homework. It is built upon the same algorithmic procedures of solution as the Assessment Module. Since each category of exercises in the database is structured into the hierarchy of types according to their difficulty, the student proceeds from the easiest types to the more complicated ones. The exercises for practicing are generated with respect to the success of the student. If the student is successful, an more difficult exercise is chosen. And vice versa, the student receives an easier exercise in case he fails. In this manner the ORGANON adapts to the rate of learning of individual students.

The main function of the Practicing Module is to check the student's solution (usually the check of equivalency) and to alert when mistake appears (at the end of each step). Such a mistake alarm is the feedback, which students require most of all. Since the check of the solution rests in the equivalency check, it limits in no respect the student's free will in choosing the way of solving the exercise.

The main control function of the Practicing Module will be gradually extended into an interactive help. The help will be able to give advice for the next step or to perform that step. The help is built upon experiences from consultations given in person, when students solve the exercises under the auspices of the teacher. The problems students above all deal with are always the same. Hence the help can be transformed into an automatic way following the practice of the personal dialog between the student and the teacher.

Students may use the Practicing Module in three different ways. Firstly, they can just ask for the example solution so the web tutor shows the procedure of solving the exercise step by step providing relevant explanations. Secondly, they can try to solve the exercise on their own, while the application controls their progress automatically at the end of each step, and alerts them in case of mistakes. Then they may try to find and correct the mistake independently, or ask to be shown and explained the mistake. They can also ask for hints for the next step, or for demonstration and explanation of that step. Finally, students may solve the exercise independently (without automatic control) and ask for correction and grading when finished in the same way as in the case of graded homework.

In this manner the Practicing Module should handle the elementary consultations and shift practice from seminars to home study. Hence, time for much more sophisticated topics will be saved in lectures and seminars.

6 Future Plans

The ORGANON has first been used in the teaching process at the University of West Bohemia in Spring 2007 — the Assessment Module to its full extent, the Practicing Module only partially (it currently has only elementary help facilities). Afterwards, the system will be tuned up, according to the experiences gained from usage. Especially the interactive help of the Practicing Module could be finished based on experience from students using it. Meanwhile, the database will be further extended (quantitatively and qualitatively) by adding not only new types, but also the whole new categories of exercises. Categories for the square of oppositions, formalization, deduction, and syllogistic are in progress. Finally, it is planned to add explanatory texts to the Practicing Module, so that the application could serve not only as an exercise-book, but moreover as an independent e-textbook of elementary logic.

The ORGANON has no unusual software or hardware claims, so it may be used also at other universities. Therefore, follow-up projects will be held to create comfortable user interface also for teachers and not only for students. Afterwards, teachers will be able to extend the database and to create their own structure of exercises and homework to accomplish their own courses.

No doubt the electronic way of teaching may never equal the individual contact-based teaching. It should serve as a precious assistant for practice. Suddenly, it is now possible to grant each student a personal tutor to receive immediate feedback during practice at home, right when the student wishes to benefit from its services. Usually students need nothing else but the feeling that somebody is watching over the progress of their solution - this feeling is the only condition for them to be able to handle the exercise by themselves successfully. And this is something that computers can do much more patiently and attentively than a teacher.

It is claimed quite often, that the transformation of studying into an electronic form diminishes the requirements demanded from students and lowers the level of resulting knowledge and skills. The result of ORGANON should be completely the opposite. To give students such a tutor means that it is possible to increase the requirements of basic logic courses, without making these courses unrealizable for students and ungovernable for teachers.

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