

# Collaborative Exercise Management

Ralf Wimmer, Tobias Nopper, Marc Herbstritt, Christoph Löffler, Bernd Becker

Institute of Computer Science, Albert-Ludwigs-University, 79110 Freiburg im Breisgau, Germany  
{wimmer, nopper, herbstri, loeffler, becker}@informatik.uni-freiburg.de

**Abstract:** In this work, we report on a novel tool for managing exercises used in a collaborative course organization environment at university. Our approach focuses on the separation of the content of the exercises and its layout. The latter is based on the typesetting system LaTeX. Content management of the exercises is established by a web-based interface. As a whole, our tool provides a time-saving and unambiguous workflow for collaborative, time- and place-independent exercise organization.

## 1 Introduction

A frequent and mostly time-consuming task in course administration at university is the generation of exercises, particularly for subjects related to mathematics, physics, and computer science. Typically, from an organizational point of view, a course decomposes into two parts: the lecturer and the course assistant part, respectively. On the one hand side the lecturer is responsible for the course topics and the corresponding preparation and presentation (e.g., slide generation, presentation in the lectures). On the other hand, the course assistant has to take care for the remaining tasks, i.e., technical organization, administrative support of the students, and especially the organization of exercises. The exercise organization itself can again be split into exercise administration and exercise generation. The focus of this paper is on exercise generation, whereas the main motivation are the following observations:

- Since course assistant vacancies are regularly filled with new persons, new course assistants have to familiarize themselves with the existing work-flow for course organization and exercise generation. These tasks take a non-negligible amount of time.
- Different people do organize exercises differently, resulting in inhomogeneous formats. We have experienced various formats ranging from LaTeX, MS Word to even digitally-scanned hand-written notes.
- Especially for introductory courses, which are held regularly, there is a huge number of exercises that have accumulated over the years. In case different people have organized these courses, it can be assumed that it is hard to get a quick overview.
- Finally, merging of already existing exercises, available in incompatible formats only, is a tedious task.

To overcome these limitations one has to tackle two problems. The first is an industrial psychology problem: People are only willing to use new tools when there are obvious advantages compared to the existing work-flow. One of the biggest advantages is that using our new tool saves a lot of time. The second problem is a technical one: If one wants to separate the content of the exercise and its layout, there must be a reliable and flexible format for the description of the exercises.

In this work, we present a tool we have developed within our course organization environment. The exercise administration of our environment is based on a web-based Learning Management Systems as described in (Schubert & Becker, 2003). The novel tool presented in this paper for exercise generation aims at providing a practical solution to both problems mentioned above. The technical problem is basically solved by using LaTeX as exercise description format. Based on this, we built a web-based interface for exercise management. Using this interface, it is possible to arrange new exercise sheets using the shopping cart concept familiar from virtual internet stores. Due to the ubiquitous confrontation with today's internet technologies, the web-interface is very easy to use. Finally, we have experienced that the time for preparing a new exercise sheet – which involves the creation of new exercises as well as the reuse of existing ones – could be reduced from several hours to some minutes. Clearly, this huge time-saving solves the second problem, since all people involved in course administration and exercise management are willing to use the new tool.

## 1.1 Related Work

Heussen et al. (2005) presented the Online Examination System (OES), which provides an intuitive user interface for preparation, administration, execution and evaluation of online-exams. Teachers are supported in creating a pool of exercises and media to be used within. The usage of various types of exercises is possible, the most of which can be evaluated automatically. Yet, this system is limited to online exercises and simple text. Additionally, due to limitations of HTML, the generation of complex formulas is not trivial as it is in LaTeX.

Other tools supporting the administration of tutorials like WebAssign (Brunsmann et al., 1999) or eCLAUs (Behringer et al., 2004) do not focus on the creation of exercises, but the organization of exercise groups, the submission and correction of students' solutions to exercise sheets. The creation of exercises is more or less restricted to multiple-choice exercises and free-text exercises in HTML. Although conceptually supported by WebAssign through a number of Java applets, the input of formulae is rather tedious.

There is also a number of systems like OASYS (Bhalerao & Ward, 2001) and Peer Grader (Gehring, 2001) managing peer assessments in which students can review other students' solutions to exercises. Both systems are restricted to the input of exercises in HTML or the upload in PDF.

The paper is structured as follows: Section 2 explains the technical aspects using LaTeX as description format. The portal-like web-interface is described in Section 3. In Section 4, we report on our experiences with the new tool. Finally, Section 5 concludes the paper and discusses several possible extensions for future work.

## 2 LaTeX-Classes for Typesetting Exercise Sheets

LaTeX is a well-known typesetting system used particularly for scientific publications in areas related to mathematics. It is the outstanding capability of formatting complex mathematical formulas for which LaTeX is famous and popular, see (Knuth, 1979; Kopka & Daly, 2003; Mittelbach et al., 2004) for a comprehensive treatment. Many additional resources can be found in the Comprehensive TeX Archive Network (CTAN, 2006), which makes LaTeX one of the most powerful typesetting systems. The simple fact that it comes for free, emphasizes the unique position of LaTeX. LaTeX also has the advantage of being a completely text-based input format, which makes it very easy for scripts to process or generate LaTeX files, that can then be automatically converted into further formats, e.g. PostScript or PDF<sup>1</sup>. This is a very important issue considering web-based applications. Furthermore, it is the case that historically most of our (several hundred) existing exercises were made using LaTeX. Taken together, the discussion above led to the decision to base our exercise sheet generator on LaTeX. In the following we will describe the suggested concept for managing exercises in a directory tree. Then, we will present how to build an exercise sheet by including single exercises. To do so, we have developed a specialized LaTeX class for our purpose that we will describe along.

### 2.1 Exercises

#### *Organization of the Exercise Files.*

Each single exercise is stored in a LaTeX File, together with its associated files (such as graphics etc.) in a separate directory. The name of the directory consists of a unique 4-digit number (chosen randomly) and a letter for each variant of an exercise.<sup>2</sup> The exercise directories are grouped by the lecture series they belong to. Our running example is an exercise that is used in a lecture set "Introduction to Computer Systems" (Bryant & O'Hallaron, 2003; Becker et al., 2005), in which a property of two's complement numbers is to be proven. This exercise is the variant b of the exercise No. 154 in the same lecture set and thus located in ICS/a0154b/0154b.tex. A graphic belonging to this exercise would be located in the same directory and would share the same alphanumeric prefix (e.g. ICS/a0154b/0154b-adder.eps for the example given above).

---

[1] PostScript and PDF are registered trademarks of Adobe Systems incorporated

[2] A variant is an exercise that is very much alike, yet different to another exercise (e.g. consider different numbers for a calculation exercise).

### Contents of the exercise files.

An exercise LaTeX file contains all information relevant for a single exercise. It may consist of up to five parts (see Figure 1):

1. A set of important `\keywords{}` for this exercise.
2. A `\history{}` providing information in which exercise sheets this exercise has already been used
3. The description of the `{exercise}` itself.
4. The `{solution}` to this exercise.
5. A short `{sketch}` of the solution.

Due to a modified version of `\includegraphics`, pictures can easily be included by their name (without path and prefix) and can be referenced as usual by using `\label` and `\ref`. By using `\cref`, it is even possible to do cross-references between different exercises (yet of course within a single exercise sheet).

```
\keywords{Two's Complement} \history{r-ics-wt05}

\begin{exercise}
Show that two's complement numbers can be negated by
inverting every bit and adding a ``1'' at the least
significant position.
\end{exercise}

\begin{solution}
Let  $[a] = [a_n, \dots, a_0]$ . It holds that  $\bar{a}_i = 1 - a_i$ .
\begin{align*}
[\bar{a}] &= \sum_{i=0}^{n-1} \bar{a}_i 2^i - \sum_{i=0}^{n-1} a_i 2^i + 1 \\
&= \sum_{i=0}^{n-1} (1 - a_i) 2^i - \sum_{i=0}^{n-1} a_i 2^i + 1 \\
&= \sum_{i=0}^{n-1} 2^i - 2 \sum_{i=0}^{n-1} a_i 2^i + 1 \\
&= \frac{2^n - 1}{2} - 2 \sum_{i=0}^{n-1} a_i 2^i + 1 \\
&= - \sum_{i=0}^{n-1} a_i 2^i + a_n 2^n \\
&= -[a].
\end{align*}
\end{solution}
```

Figure 1: An exercise file (ICS 0154b) with exercise description and corresponding solution.

## 2.2 Exercise Sheets

While the exercise files are only fragments, the exercise sheet is a complete LaTeX file that includes the exercises and can be processed with the usual LaTeX compilers<sup>3</sup>. The LaTeX class “exercise.cls” is loaded by calling `\documentclass{exercise}`. By default, only the exercises and no solutions are generated; the class option “withSolution” takes care of that. Meta-information that is necessary to build the exercise sheet can be set by using the commands `\coursetitle`, `\courseorganizer`, `\exercisenumbers`, `\submission`, `\pathToExercises` and `\date`; all these commands are self-explanatory. The exercises themselves can be included by invoking `\includeExercise` with the alphanumeric exercise ID and (optionally) the number of points the students receive for a correct solution. Figure 2 shows an exemplary exercise sheet LaTeX code and Figure 3 the generated PDF-file.

## 3 Web Interface for Exercise Sheet Generation

To make the creation of exercise sheets even easier, we developed a web interface that allows to search the set of existing exercises, to create variants and new exercises, to generate exercise sheets with selected exercises and to store sheets. The use of a web portal that is globally accessible has a further advantage: Every time a course assistant has to attend a conference or a workshop, the sheets had to be prepared before the conference and hence, sometimes did not match the lecture. This problem is solved by the web interface.

[3] This also means that the class file can be used independently from the web interface.

```

\documentclass[withSolution]{exercise}
\coursetitle{Introduction to Computer Systems}
\courseorganiser{Prof.~Dr.~John Doe (Lecturer)\
Michael Myers (Course assistant)}
\exercisenummer{13}
\submission{Friday, January~27~2006, 17:00, upload using the web-portal}
\date{Friday, January~20~2006}
\pathToExercises{/usr/Staff/Teaching/ExerciseCollection/ICS}

\begin{document}
\includeExercise[3]{0154b}
\includeExercise[6]{0155}
\end{document}

```

**Figure 2:** LaTeX Code of an Exercise Sheet.

### ***Information Storage***

We use a redundant storage for the exercises and their meta-information: A database system contains all meta-data of the exercises as well as the text of the exercises themselves to allow an efficient full-text search. Furthermore, it contains a preview image of every exercise. Additionally, all exercises are stored in a directory tree as described in the previous section. Each time a new exercise or a variant is created, it is inserted in both the database and the directory tree. We consider sole database storage as insufficient, since LaTeX only works on files and we additionally want to be able – as a backup solution – to generate exercise sheets without the web interface. As shown in Figure 4, the creation of an exercise sheet mainly consists of the following steps: First, the assistants of the lecture create, modify and/or select some exercises. Second, they enter the meta-data of the sheet, e.g. the name of the lecture and the deadline. Third, they can use the preview function to check the contents of the sheet and the layout; they can change the meta-data, add or remove exercises until the sheet is satisfactory. As a last step, the users can download the exercise sheet and the solution in PostScript or PDF format.

### **3.1 Handling of Exercises**

Entering the web portal, the users can create a new exercise, search for an existing exercise or load a complete exercise sheet that has been stored previously. For the latter see the next section.

#### ***Creating a New Exercise***

If the users select to create a new exercise, they are presented an input form in which they can enter the LaTeX sources for the exercise, its solution, and a solution sketch. Furthermore, they can specify keywords, for which lectures the exercise has already been used and which lecture series it belongs to. The exercise can then be stored in the database for later use.

#### ***Searching for Existing Exercises***

The users can search the database for all exercises containing a given search term (see Figure 5). The search results are ranked depending on the place the search term occurs in the exercise (among the keywords, in the text of the exercise, the solution or the sketch) and the number of occurrences such that best results appear first. The users are then presented with a sorted list of hits where they can

- view more details of an exercise (see below),
- select an exercise for modification or correction, or
- add an exercise to the current exercise sheet.

#### ***Detailed View of an Exercise***

We have implemented several detailed views of an exercise, from a text excerpt of the exercise and a printout of the complete LaTeX source code up to the probably most useful view, an image that shows the exercise, typeset by LaTeX, as it will appear on the sheet.



**Introduction to Computer Systems**  
**Solution of Exercise Sheet 13**

**Exercise 1** (3 points)

Show that two's complement numbers can be negated by inverting every bit and adding a "1" at the least significant position.

**Solution:**

Let  $[a] = [a_n, \dots, a_0]$ . It holds that  $\bar{a}_i = 1 - a_i$ .

$$\begin{aligned} [a] + 1 &= \sum_{i=0}^{n-1} \bar{a}_i 2^i - \bar{a}_n 2^n + 1 \\ &= \sum_{i=0}^{n-1} (1 - a_i) 2^i - (1 - a_n) 2^n + 1 \\ &= \sum_{i=0}^{n-1} 2^i - 2^n + 1 - \sum_{i=0}^{n-1} a_i 2^i + a_n 2^n \\ &= \frac{2^n - 1}{2 - 1} - 2^n + 1 - \sum_{i=0}^{n-1} a_i 2^i + a_n 2^n \\ &= - \sum_{i=0}^{n-1} a_i 2^i + a_n 2^n \\ &= -[a]. \end{aligned}$$

**Exercise 2** (6 points)

Let  $y \in \mathbb{B}^{24}$  and  $\text{sext}(y) := y_{23}^8 y$ . Prove that  $[y] = [\text{sext}(y)]$ .

**Solution:**

**Lemma:** Let  $a \in \mathbb{B}^n$ ,  $a = a_{n-1} \dots a_0$ . Then  $[a] = [a_{n-1}a]$ .

**Proof:**

$$[a_{n-1}a] = -a_{n-1} \cdot 2^n + \sum_{i=0}^{n-1} a_i \cdot 2^i = -a_{n-1} \cdot 2^n + \left( a_{n-1} \cdot 2^{n-1} + \sum_{i=0}^{n-2} a_i \cdot 2^i \right) = -a_{n-1} \cdot 2^{n-1} + \sum_{i=0}^{n-2} a_i \cdot 2^i = [a]$$

Thus:  $[y] = [y_{23}^1 y] = [y_{23}^2 y] = \dots = [y_{23}^8 y] = [\text{sext}(y)]$ .

**Deadline:** Friday, January 27 2006, 17:00, upload using the web-portal

Figure 3: The PDF file generated by the LaTeX Code shown in Figure 2

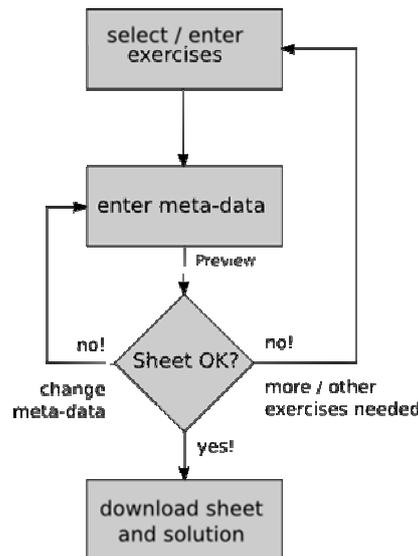


Figure 4: Flow sketching how to create a new exercise sheet.

### *Modifying or Correcting an Exercise*

When the users find an exercise that comes close to their needs, yet does not completely match them, they can create a variant of that exercise.<sup>4</sup> As mentioned in the last section, such a variant will carry the same number as the original exercise plus a distinct letter. In the past, we sometimes ran into problems with exercises that contained errors. Therefore, we added the possibility to correct exercises. The interface is the same as for the creation of a variant, yet here the old exercise is replaced by the corrected version.

### *Adding an Exercise to the Sheet*

Adding an exercise to a sheet works analogously to the well-known “shopping cart”-concept, which in this version holds exercises, with the possibility to add more and to remove some of them again. After the selection phase, the users can supply meta-information and arrange the exercises on the sheet, which will be presented in the next section.

## 3.2 Generating Exercise Sheets

Before completing the exercise sheet, the users should supply some meta-information (see Figure 6), e.g.:

- the name of the course,
- the deadline for submission,
- the points of the exercises, and
- the order of the exercises.

By using the preview function, which shows the pages of the complete exercise sheet as enlargeable thumbnails, the users can check the layout and the content of the sheet. They can change the meta-information and remove, add and reorder exercises until the sheet is satisfactory. Finally, the users can download PostScript- or PDF-documents for the sheet, the solution and solution sketches. Furthermore, exercise sheets can be stored in a sheet catalogue.

## 4 Experiences

We started to use the described tool two semesters ago and applied it to almost all of our courses. Although most of the courses had been provided for several years (e.g., fundamental introductory courses), there also were new courses for which no exercises existed yet. For the familiar courses, we had to adapt all the existing exercises to the new format. Clearly, this took a non-negligible amount of time. However, our evaluation showed that the

[4] Consider a modification of some numbers or the omission of some parts of the exercise.

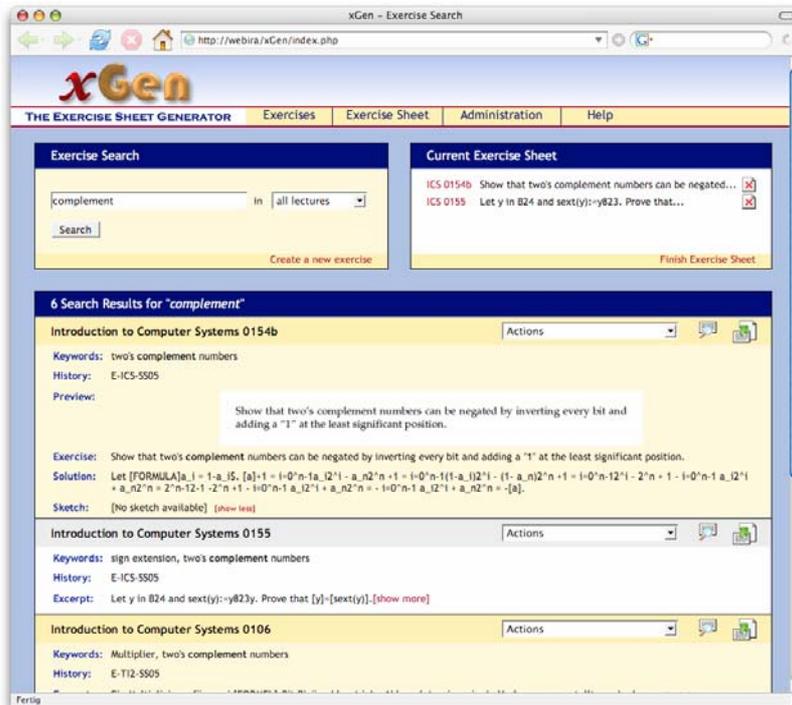


Figure 5: Screenshot of the Search page

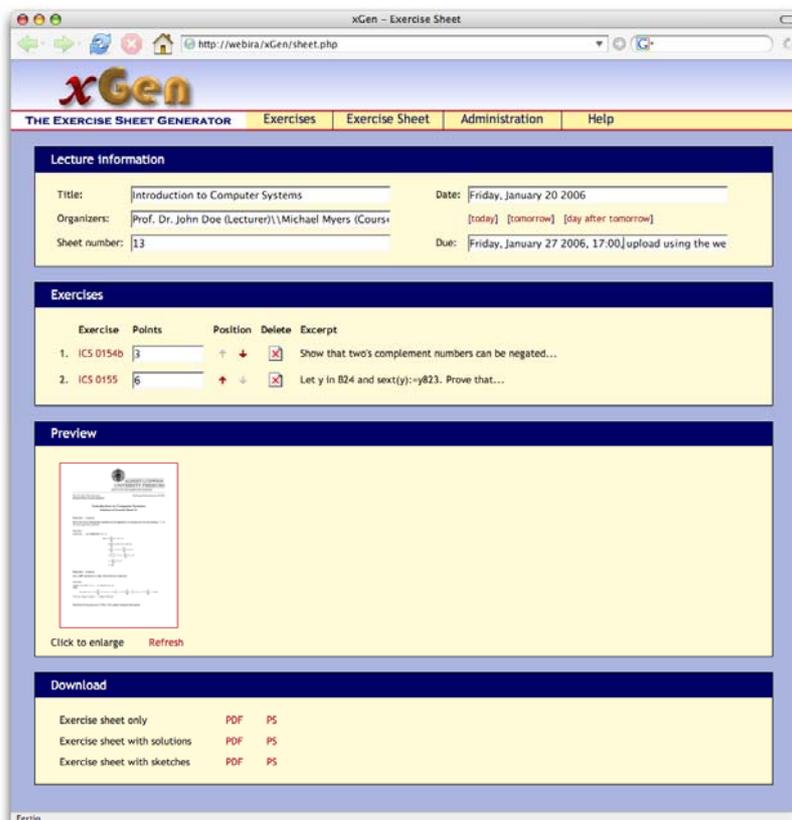


Figure 6: Screenshot of the page for the preparation of a new exercise sheet.

generation of new exercises did not cause any time consuming overhead compared to the situation before. The authors of the new exercises only had to respect the dedicated LaTeX environments. After the “new” workflow for exercise generation had been presented to our working group, there were only minor problems for the people to apply the new tool; typically, the problems could be solved by a simple phone call to one of the developers. Due to the simple structuring scheme and the easy-to-use web-interface all of the involved course assistants accepted the application of the new tool. For evaluation, we interviewed those course assistants that had to use our tool after each semester. Besides some constructive comments, all of them confirmed that the tool is easy to use and – the most important point – very timesaving. Clearly, since all of them are computer scientists, the acceptance threshold can be assumed to be lower than for other academics, mainly because they are used to work with LaTeX. Still, we suggest that our tool can be applied effectively by course assistants from different areas, since the web-based interface sufficiently abstracts from the technical backend.

## 5 Conclusion and Future Work

We presented a tool for managing exercises used in a collaborative course administration environment at university. Our tool is based on the free LaTeX typesetting system with superior abilities in handling mathematical formulae. Additionally, the input format for LaTeX is text-based and thus easily generated and processed by scripts. Furthermore, we provide a web-based interface that allows the generation of exercise sheets independently of time and place.

In the future we are planning to extend the web-interface to support the generation of exams; the LaTeX classes for exams are already available and in use. Furthermore, we are going to integrate the exercise sheet generator into our web-based lecture administration tool that is used for the online managing of exercise groups, students’ solution submission and correction.

## References

- Becker, B., Drechsler, R. & Molitor, P. (2005). Technische Informatik – Eine Einführung. Pearson Studium
- Behringer, F., Engeldinger & D., Weicker, K. (2004). Web-basierte Administration des Übungsbetriebs mit eCLAUS. In Engels, G., Seehusen, S., eds.: DELFI 2004, Bonn, Gesellschaft für Informatik, p. 79–90
- Bhalerao, A. & Ward, A. (2001). Towards electronically assisted peer assessment: a case study. 9(1), p. 26–37
- Brunsmann, J., Homrighausen, A., Six, H. & Voss, J. (1999). Assignments in a virtual university – the WebAssign-System. In: 19th World Conference on Open Learning and Distance Education, Vienna/Austria
- Bryant, R.E. & O’Hallaron, D. (2003). Computer Systems: A Programmer’s Perspective. Pearson Education
- CTAN (2006). The Comprehensive TeX Archive Network. <http://www.ctan.org>
- Gehring, E.F. (2001). Electronic peer review and peer grading in Computer-Science courses. In: Proceeding of the Thirty-second SIGCSE Technical Symposium on Computer Science Education (SIGCSE-01). Vol. 33.1 of ACM SIGCSE Bulletin., New York, ACM Press, p. 139–143
- Heussen, N., Baumann, M. & Blum, P. (2005). A Novel Full-Featured System for Preparation, Administration, Execution and Evaluation of Online-Exams. In: G. Richards (ed.), Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (E-Learn), p. 734 - 737.
- Knuth, D.E. (1979). TEX and METAFONT: New directions in typesetting. American Mathematical Society
- Kopka, H. & Daly, P. W. (2003). Guide to LaTeX. 4th edition. Addison-Wesley Professional
- Mittelbach, F., Goossens, M., Braams, J., Carlisle, D. & Rowley, C. (2004). The LaTeX Companion. 2nd edition. Addison-Wesley Professional
- Schubert, T. & Becker, B. (2003). A Hardware Lab Anywhere At Any Time. In: Proceedings of the 3<sup>rd</sup> International Conference on Education and Information Systems: Technologies and Applications (EISTA), Orlando, Florida, USA

## Acknowledgements

We would like to thank Larissa Wißmann, who did most of the adoption of the hundreds of old exercises into our new repository.