Enthusiast: An authoring tool for automatic generation of paper-and-pencil multiple-choice tests

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Abstract:

In this paper we describe Enthusiast *– a flexible tool for the automatic generation of pen-and-pencil multiple-choice test sheets. Enthusiast uses a database of multiple-choice questions and a test specification provided by the user to generate randomized multiple-choice test sheets suitable for machine-scoring. The questions database may be augmented with metadata tags, effectively defining user-specific questions taxonomy upon which detailed test specifications can be based. Enthusiast may be used to generate test sheets of adequate variability, speed up test administration, and ensure objective and fast grading. We have recently used Enthusiast in several courses at our faculty, for both summative and formative knowledge assessment, and received positive feedback from students.*

1 Introduction

Assessing student knowledge can be a challenging task, especially for courses with large enrolments. Open-ended question tests (e.g., short answer questions and essays) are perhaps the most simple to create, but grading them is very tedious and time consuming. If several hundred students have taken the test, results might be available only several weeks later, leaving students with no immediate feedback. More importantly, consistent grading with this type of test is difficult to achieve. In order to provide objective and consistent assessment of students' knowledge, as well as more time efficient grading, multiple-choice tests are often used. Multiple-choice test are considered a valid alternative to open-ended tests; in [1] it is even argued that "open-ended questions should be used solely to test aspects that cannot be tested with multiple-choice questions." This is especially true if questions are designed according to established guidelines, such as the ones suggested in [2].

Multiple-choice tests may be used for many forms of knowledge assessment, such as formative ones (e.g., end-of-lecture quizzes) and summative ones (e.g., written mid-term and final exams). If the number of students is relatively small, this kind of test can be held in computer equipped classrooms under teacher supervision. Unfortunately, with a large number of students this kind of knowledge assessment is often not feasible. An alternative to this are the traditional paper-and-pencil multiple-choice tests. Because multiple-choice tests can be machine-scored, significant time savings are gained over free form-tests. However, when administering multiple-choice paper-and-pencil tests in a classroom, special care must be taken to prevent test cheating. This typically means that the test must be prepared in a number of test variants. Ideally, test variants should differ not merely in the presentation order of questions and answers, but also feature slightly modified questions. Preparing such test variants manually is an extremely error prone task.

To address the above mentioned issues, we devised *Enthusiast* – an authoring tool for the automatic generation of pen-and-pencil multiple-choice tests. *Enthusiast* uses a plain-text database of multiple-choice questions and a test specification provided by the user to generate randomized multiple-choice test sheets suitable for machine-scoring. The questions database may be augmented with metadata tags that describe the topic and the type of each question, effectively defining user-specific questions taxonomy upon which detailed test specifications can be based. The variability across test sheets (the extent to which questions and answers differ across test sheets) can also be adjusted. *Enthusiast* generates test sheets in LaTeX format, a widely used document preparation system of high typographical standard [3]; the format of the sheets can of course be customized to suit specific needs.

The rest of the paper is structured as follows. In next section, we describe *Enthusiast* in more detail, while in Section 3 we discuss practical experience with *Enthusiast*. A brief comparison of *Enthusiast* with other similar systems is given in Section 4. Section 5 concludes the paper and briefly explains future work.

2 Enthusiast

Enthusiast is a stand-alone tool implemented in the functional programming language Haskell [4]. It uses a questions database and a test specification as input, and generates randomized test sheets as output.

2.1 Questions Database

Contrary to most existing examination generation software, *Enthusiast* uses a questions database encoded in a simple plain-text format rather than a full-blown database or XML files. The questions database may be organized into several files and folders. The main motivation behind this is that question editing should be kept as simple as possible, allowing the user to focus on content instead of the form. In order to improve the variability across test sheets, each question in the database may be complemented with mutually exclusive question variants, as well as a redundant number of correct and incorrect answers. Moreover, each question may be associated with user-specific tags (metadata keywords) that describe its topic and type. This effectively allows for user-specific questions taxonomy. Moreover, tags may be organized hierarchically, allowing for a more fine-grained and more comprehensive taxonomy. Based on the tag metadata, the user can provide *Enthusiast* with a detailed test specification defining the content and type of the test.

An excerpt from question database is given in Fig. 1. The questions are on Artificial intelligence and the problem of state-space search. In the question database file, user's comments are prefixed by a percent sign, while each question is labelled with a unique identifier prefixed by the '`@`' sign. This example features two questions: question `@1` (lines 6 through 34) and question `@2` (lines 36 through 47). Question `@1` comes in two variants (lines 8 through 20 and lines 22 through 34). Each question consist of the question text followed by a number of answer options; the correct options are prefixed by the '`+`' sign and the incorrect ones by the '`-`' sign. The required number of options is determined by the test type; e.g., a one-out-of-four test requires a minimum of one correct and three incorrect answer options. If a larger-than-minimum number of correct or incorrect options are provided, *Enthusiast* will randomly choose the required number of answer options. Options that for some reason or other are preferred are marked with the '!' sign; these are the options that Enthusiast will consider choosing first. A default option, marked by an '*' sign, is a sort of back-off option and will be presented last.

```
 1: % Course:  Artificial intelligence
 2: % Lecture: State-space search and problem solving
 3:
 4: theory basic search:     % tags common to this file questions
 5:
 6: @1 :blind:depthFirst algComplexity: difficulty:simple
 7:
 8: :time
 9:
10: Time complexity of depth-first search is:
11:
12: + $O(b^m)$, where $b$ is the branching factor and $m$ is maximum tree depth
13: + exponential
14: -! identical to its space complexity
15: - constant
16: - polinomial
17: - $O(bd)$, where $b$ is the branching factor and $d$ is the depth of solution
18: - $O(d)$, where $d$ is the depth of solution
19: - $O(b^{d/2})$, gdje je $b$ is the branching factor and $d$ is the depth of solution
20: -! none of the above
21:
22: :space
23:
24: Space complexity of depth-first search is:
25:
26: + $O(bm)$, where $b$ is the branching factor and $m$ is maximum tree depth
27: - $O(b^m)$, where $b$ is the branching factor and $m$ is maximum tree depth
28: -! identical to its time complexity
29: - constant
30: - polinomial
31: - $O(bd)$, where $b$ is the branching factor and $d$ is the depth of solution
32: - $O(d)$, where $d$ is the depth of solution
33: - $O(b^{d/2})$, gdje je $b$ is the branching factor and $d$ is the depth of solution
34: -! none of the above
35:
36: @2 :guided:aStar type:single
37:
38: Algorithm $A^*$ is:
39:
40: + complete and reachable
41: + informed
42: - guided
43: - heuristic
44: - nor complete nor reachable
45: - not complete but reachable
46: - complete but not reachable
47: - blind
```

Figure 1. An excerpt from a questions database.

In Fig.1, the user-specific tags are shown in bold. To make tagging less tedious, the tags in the file may be specified at three different levels, each of progressively narrower scope. At the top-most level, tags that are common to all questions in the file are specified (line 4). At the second level, each particular question is tagged (lines 6 and 36). Finally, at the third level, each particular question variant may be tagged (lines 8 and 22). Hierarchical relationship between tags is indicated with a colon. For example, tags `search`, `blind`, and `depthFirst` may be written as `search:blind:depthFirst` to reflect the fact that blind search is a kind of search procedure and that depth first search is in turn a kind of blind search. To make hierarchical tagging more convenient, we allow hierarchical tags to be broken down into parts and specified incrementally. This is accomplished by propagating tag specifications to lower scopes: a tag ending with a colon will be propagated to the immediate lower scope, while tags starting with a colon will be appended to the tag that is being propagated. In example from Fig. 1, tag `search`, being specified at the top-most level, is propagated to both questions `@1` and `@2`, while tag `algComplexity` is propagated only to the two variants of question `@1`. Thus, both variants of question `@1`, besides being tagged with `theory, basic`, and `difficulty:simple`, will also be tagged with `search:blind:depthFirst`. In addition to that, first variant of question `@1` will be tagged with `algComplexity:time`, while the second variant will be tagged with `algComplexity:space`. By the same token, question `@2`, besides being tagged with `theory`, `basic` and `type:single`, will also be tagged with `search:guided:aStar`. Question `@2` is tagged with `type:single` to indicate that its answers are somewhat overlapping and hence this question should not be used for tests in which more than one correct answer is possible (multiple-select questions).

Because *Enthusiast* generates test sheets in LaTeX, it is possible to directly use LaTeX formatting tags in both the question text and the answer options. This makes typesetting of mathematical expressions especially convenient. In Fig. 1, the mathematical expressions appear enclosed in LaTeX tags ‘`$`’. Associating images to questions is also straightforward, but will not be demonstrated here.

2.2 Test Specification

The tag metadata provided in the questions database effectively defines user-specific questions taxonomy. Based on this taxonomy, the user can provide *Enthusiast* with a detailed test specification regarding the content and the structure of the test. For example, the user may specify that the test should consist of six one-out-of-four questions, of which four are related to the today’s lecture, two to the specific topic of the last week’s lecture, and of which one should be more difficult than the other five. Based on this test specification, for each test sheet *Enthusiast* will choose six appropriate questions from the database, as well as one correct and three incorrect answer options for each of them. To even further improve the variability across test sheets, the presentation order of questions and answer options may also be shuffled. On the other hand, if required, one can specify that certain questions or answers should be common to all test sheets, or that their presentation order should be fixed as well. This way, the user is given full control over the content and variability of the test, ensuring a fair assessment of students’ knowledge.

```
 1: % Course: Artificial intelligence
 2: % Test:   Quiz 1
 3:
 4: AI_2008 01  % course ID, test ID
 5: 1 4 6       % max correct, num options, num questions
 6:
 7: theory basic -disclosed  % tags common to this test
 8:
 9: 1  introduction
10: 2! search:blind
11: 3  search difficulty:simple
12: 4  aStar | -difficulty:simple
13: 5  complexity:space !
```

Figure 2. Example of a test specification.

An example of a simple test specification file is given in Fig. 2. This specification is for an end-of-lecture quiz with six one-out-of-four questions. In line 5, the maximum number of correct answer options, number of total answer options, and number of questions is given (note that, although *Enthusiast* can generate multiple-select tests, this type of test has been argued against in [5]). In line 7 we specify that this quiz contains questions tagged with `basic` and `theory`, but not tagged with `disclosed` (say we decided to use this tag for questions that are already known to the students). Then follows a more detailed specification for five out of six questions, leaving one question fully unspecified. The topic and type of each question is defined by specifying which tags this question should (or should not) have. For example, we specify in line 11 that question 3 should be about state-space search (tag `search`) and rather simple (tag `dificulty:simple`). We can also build logical expressions to express more complex specifications. For example, in line 12 we specify that question 4 should have tag `aStar` or not have tag `difficulty:simple`. Note that mutual exclusivity of question variants is automatically enforced by *Enthusiast*.

Based on a test specification, *Enthusiast* will choose at random five suitable questions from the questions database. Because nothing is specified for the sixth question, *Enthusiast* is free to make a random choice among all questions in the database, provided these are tagged with `basic` and `theory` and not tagged with `disclosed`. Unless question number is marked with an ‘`!`’, the presentation order will also be randomized. In example from Fig. 2, question 2 will always appear second, whereas the presentation order of other questions will vary from sheet to sheet. To constrain the variability of a particular question, one can add a ‘`!`’ at the end of a question specification, as we did with question 5 in Fig. 2. This has the effect of *Enthusiast* not varying the question among the test sheets. Thus, once *Enthusiast* has chosen a question that is tagged with `complexity:space`, the one and the same question (or one of its variants) will appear on each test sheet. We could have suppressed variability even further by typing ‘`!!`’ instead of ‘`!`’, which would settle on a question variant, or even by typing ‘`!!!`’, which would additionally settle on the answer options.

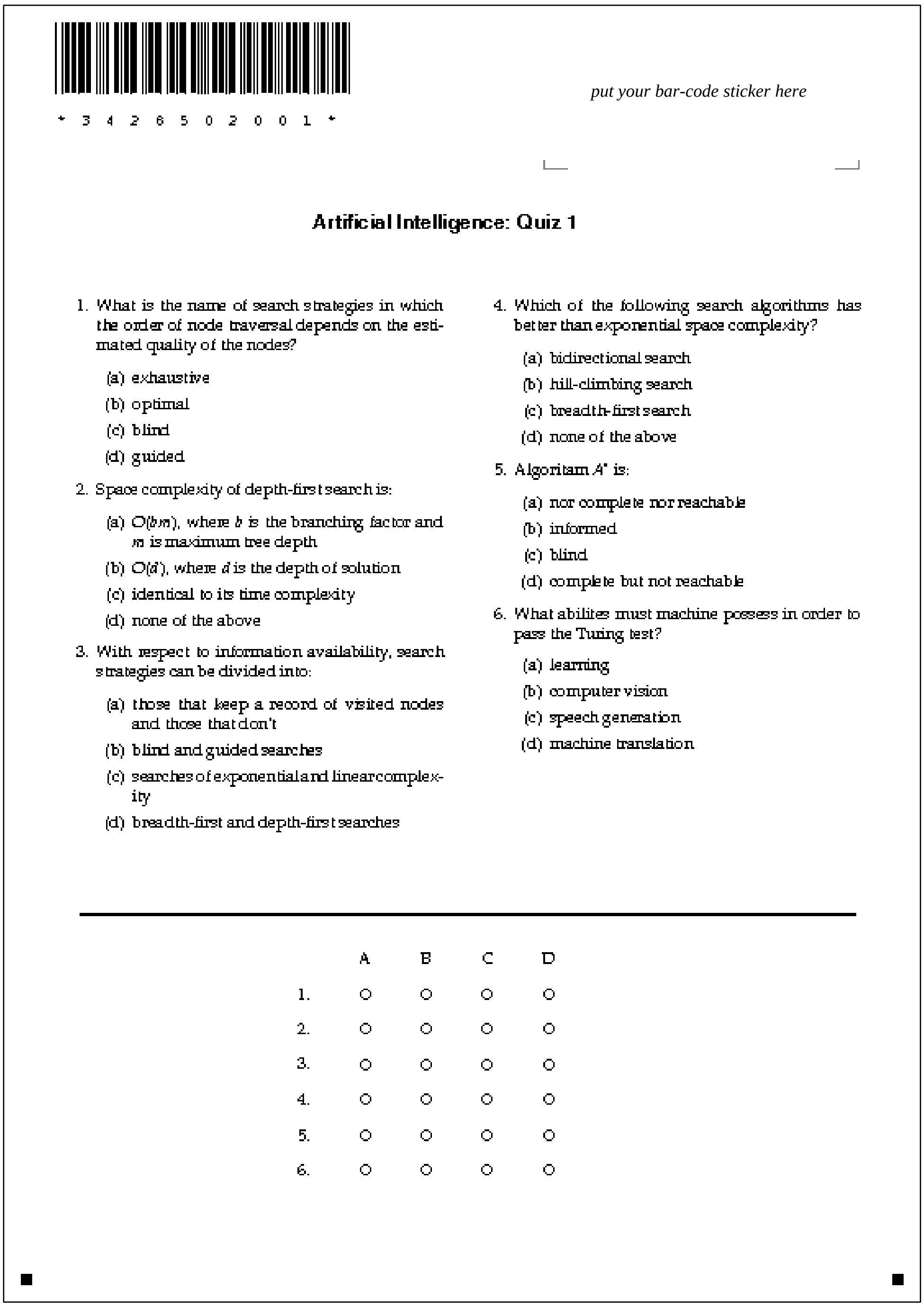
2.3 Test Generation

Using the questions database and a test specification, *Enthusiast* generates automatically a required number of paper-and-pencil test sheets (this number is given as command-line argument). Questions that meet the test specification constraints, and the corresponding answer options, are chosen at random from the questions database. However, if *Enthusiast* cannot meet these constraints, it will complain to the user and ask him or her to revise the test specification. This typically happens if a question with specified tags does not exist in the database, but it can also be that the specification is simply over-constrained and thus unsatisfiable. When choosing among questions from the database, *Enthusiast* will ignore and warn about questions that are erroneous (e.g., have two identical answer options) or inadequate (e.g., do not contain a minimal number of correct and incorrect answer options for a given test type).

Because questions and answer options are chosen and ordered at random, test sheets will differ among themselves to the extent allowed by the test specification and the size of the questions database. To give the user a sense of that variability, upon generating the test sheets *Enthusiast* will compute and report the mean number of overlapping questions between two test sheets. Based on this feedback, the user can decide whether he or she wishes to improve test variability by lessening the test specification constraints or by adding a few more questions variants to the database.

The format of the test sheets is determined by a customizable LaTeX template. The template defines the typographic appearance of the test sheet, such as positioning of questions on the sheet, font, title, as well as additional graphic elements such as test sheet bar-code, etc. User can change this template to suit his or her needs. In this way, the user can use full power of LaTeX to produce not only functional but also aesthetically pleasing output.

After generating the test sheets, *Enthusiast* produces two files. First file is a LaTeX document containing the specified number of test sheets. Using LaTeX, this document can be complied into a high-quality Post-Script or PDF format. In Fig. 3 we give an example of a single test sheet generated using questions database from Fig. 1 and test specification from Fig. 2. This test sheet features a computer-readable answer form for automatic grading, a point we discuss below. Second file output by *Enthusiast* is a list of correct answers for each test sheet.



* 3 4 2 6 5 0 2 0 0 1 *

put your bar-code sticker here

Artificial Intelligence: Quiz 1

1. What is the name of search strategies in which the order of node traversal depends on the estimated quality of the nodes?
   (a) exhaustive
   (b) optimal
   (c) blind
   (d) guided
2. Space complexity of depth-first search is:
   (a) $O(bm)$, where b is the branching factor and m is maximum tree depth
   (b) $O(d)$, where d is the depth of solution
   (c) identical to its time complexity
   (d) none of the above
3. With respect to information availability, search strategies can be divided into:
   (a) those that keep a record of visited nodes and those that don't
   (b) blind and guided searches
   (c) searches of exponential and linear complexity
   (d) breadth-first and depth-first searches
4. Which of the following search algorithms has better than exponential space complexity?
   (a) bidirectional search
   (b) hill-climbing search
   (c) breadth-first search
   (d) none of the above
5. Algoritam A^* is:
   (a) nor complete nor reachable
   (b) informed
   (c) blind
   (d) complete but not reachable
6. What abilites must machine possess in order to pass the Turing test?
   (a) learning
   (b) computer vision
   (c) speech generation
   (d) machine translation

	A	B	C	D
1.	○	○	○	○
2.	○	○	○	○
3.	○	○	○	○
4.	○	○	○	○
5.	○	○	○	○
6.	○	○	○	○

Figure 3. An example of a test sheet generated by *Enthusiast*.

3 Practical Experience

Enthusiast was recently used in three computer science courses offered by our faculty: Computer graphics, Scripting languages, and Artificial intelligence. For the latter it was used to generate test sheets for both summative (mid-term and final exams) and formative (end-of-lecture quizzes) knowledge assessment. Although multi-choice tests were used in both cases, the tests obviously had to differ substantially in both form and content. In what follows, we present our practical experiences in using *Enthusiast* for course on Artificial Intelligence.

3.1 Summative Testing

For summative testing, we used *Enthusiast* to generate four to eight distinct test sheets, each containing 20 questions for mid-term exams and 25 questions for final exams. Each question provided six answer options. We used one and the same questions database for each test. This database totals over 200 questions and over 350 question variants, and is well augmented with metadata tags. Among others, in this database we distinguish between theory questions (tagged with `theory`) and problem questions (tagged with `problem`). For each exam, we wrote a test specification that ensures a good coverage of the course material, but also ensures that the majority of the questions are problem questions. The presentation order of questions, the presentation order of answers, and the answer options themselves were allowed to vary among sheets. However, in order to ensure fair assessment of students' knowledge, we decided to constrain somewhat the variability of questions themselves. In our view, for summative testing it is important that tests have identical questions, though it might be acceptable or even desirable that tests differ in question variants. As explained in Section 2.2, such constraints can easily be enforced by making *Enthusiast* settle on questions or question variants across all test sheets. In order to minimize test cheating, we allowed for question variants, but took care that variants differ only slightly. Following the recommendations from [6], we decided to penalize for wrong answer in order to prevent blind guessing.

One obvious advantage of multiple-choice tests is that they can be scored fast, especially if machine-scored. To support machine-scoring of tests, students marked their answers on a separate computer-readable answer sheet with student ID number encoded in bar-code. Based on the answers file generated by *Enthusiast*, the sheets were machine-scored and results were usually announced within three hours.

3.2 Formative Testing

For formative testing, we used *Enthusiast* to generate end-of-lecture quizzes with six basic comprehension questions, each with four answer options (see Fig. 3). We used the same questions database as in the above case, but had *Enthusiast* chose only the very basic theory questions (those tagged with both `theory` and `basic`), and of course only those related to the particular lecture. For each quiz, we wrote a test specification that ensured that questions are well balanced among lecture topics (see Fig. 2).

Because we wanted the end-of-lecture quizzes to contribute to the final score, and because students took them in a full classroom (over 90 students took the course), preventing test cheating became a major concern. Thus, to minimize the chance of cheating, we generated a different test sheet for each individual student. The test sheets differed in questions and their presentation order, as well as the answer options and their presentation order. Each quiz used on average 20 questions from the questions database. Even with such moderately-sized questions database, for each quiz we managed to generate more than 90 test sheets with an average of less than three overlapping questions between two sheets.

Rapid feedback to students is even more important for formative than for summative tests. While machine-scoring of separate answer-sheets works well for summative tests, it is not feasible for end-of-lecture quizzes because distributing individual answer sheets to the students would take up far too much time. Instead, our approach was to combine together the answer and the test sheet. Test sheets had an answer form printed on them, and the students were asked to put on the sheets their own bar-code stickers (given to them at the beginning of the semester). Moreover, the LaTeX template for test sheets was modified so that each test sheet featured a unique bar-code identifier (see Fig. 3). Machine-scoring of tests then paired the student identifier with sheet identifier, and read off the answers that the student had provided on the same sheet. The results were usually announced within an hour's time, thereby providing rapid feedback to students. Seven end-of-lecture quizzes were administered during the semester, with positive comments from students.

4 Related Work

There exists a number of multiple-choice test generation software, such as *Question Mark* [7], *ExamGen* [8], *HotPotatoes* [9], and *TestPilot* [10]. The latter two generate web- or computer-based tests and cannot actually be used to produce paper-and-pencil tests. *Question Mark*, on the other hand, is a full-blown commercial product for authoring, scheduling, delivering, and reporting on tests. Although its functionality extends far beyond that of *Enthusiast*, *Question Mark* is not really meant for paper-and-pencil testing and seems to lack some peculiar features, such as the ability to control variation across test sheets or define mutually exclusive question variants.

Most similar to *Enthusiast* is *ExamGen*, a GUI-based Java application that can be used to both manage multiple-choice questions (stored in a Microsoft Access database) and generate printable test sheets (in HTML format). Besides multiple-choice questions, the user can define short-answer questions, the inclusion of which, however, prevents full machine-scoring of the test. A useful feature of *ExamGen*, one that is missing in *Enthusiast*, is the ability to keep track of when a particular question was last used in an exam. On the other hand, *ExamGen* is missing a number of important features, notably the ability to generate randomized test sheets and the possibility to provide a redundant number of correct and incorrect answer options. Based on our practical experience, we consider these features to be absolutely necessary for large class assessments. Moreover, while in *Enthusiast* one can build elaborate questions taxonomy with respect to both the topic and type of questions, in *ExamGen* one can merely group questions according to user-defined categories. The possibility to build taxonomies of questions and to refer to these in test specifications is important as it supports the use of one and the same question database not only for different tests, but also for different kinds of tests.

5 Conclusion and Future Work

Enthusiast is a flexible tool for the automatic generation of pen-and-pencil multiple-choice test sheets. It uses a plain-text database of multiple-choice questions and a test specification provided by the user to generate randomized multiple-choice test sheets suitable for machine-scoring. In order to improve the variability across test sheets, each question in the database may be complemented with mutually exclusive question variants, as well as a redundant number of correct and incorrect answers. The questions database may be augmented with metadata tags, effectively defining user-specific questions taxonomy. The tags themselves may be organized hierarchically, allowing for more fine-grained and more comprehensive taxonomy. Based on this taxonomy, a test specification can be written that gives the user full control over the content and type of the test, and the variability across test sheets.

Enthusiast has been used in several courses at our faculty, for both summative and formative knowledge assessment. Based on our experience, we are confident that *Enthusiast* can be used to generate test sheets of adequate variability, provide for significant time savings, and ensure rapid feedback to students.

As part of future work, we intend to develop a web-based interface to *Enthusiast* that integrates test authoring, test sheets generation, and automatic grading. If the need arises, we will consider how to extend test specification format to allow for more flexible specifications. We also intend to extend the tagging system to keep track of when a particular question was used in an exam.

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