Abstract
The growing popularity of massive open online courses (MOOCs), which often have enrollments upwards of 100,000 students, presents new technical challenges for automatic grading in domains that require hand-drawn solutions. Since no comprehensive solution yet exists, our research proposes to address this problem through the development of a software platform that we call CourseSketch. Our system will enable instructors to "draw" key solutions directly into the software. It will use those 'keys' to not only automatically grade student submissions, but also incrementally provide both high- and low-level feedback to the student. Our pilot system will initially focus on the domains of engineering statics (truss problems, free-body diagrams, etc.), basic chemistry, and Japanese kanji. It will be designed to be extensible to additional domains. This pilot will be deployed in a classroom beginning in the Spring 2014 semester to ensure accuracy, functionality, and ease-of-use.

Introduction and Background
With the advent of new technologies, students have a variety of new ways to access courses. The internet has enabled instructors to reach and interact with numbers of students that were not possible before. Today, schools such as Stanford University and the University of Washington are offering free online courses with unlimited capacity. As such, the enrollment of these courses can regularly have over 100,000 students. The schools such as Stanford University and the University of Washington are offering free online courses with unlimited capacity. As such, the enrollment of these courses can regularly have over 100,000 students. While these new learning interfaces have a widespread impact, they are still plagued with some unique challenges.

Limited Feedback:
- To handle the volume of students, the online courses often lose their effectiveness as a personalized learning environment. Existing solutions are generally restricted to offering only right/wrong feedback.

Limited Problem Types:
- In addition to limited feedback, current solutions provide uncertain and/or limited forms of automatically grading questions. To provide automatic grading, assignments need to contain only multiple choice and true/false questions. Some solutions utilize crowdsourcing for grading the assignments; however, this method introduces a great deal of uncertainty and lack of uniformity to the grading of students' assignments.

Limited to Specific Domains:
These constraints further limit the current problem types to specific domains. Domains that involve hand-drawn types of solutions generally eliminate such assignments from their MOOCs.

Objective
Our goal is to develop the platform, CourseSketch, to address these problems, to provide many additional features, and to create a better online learning environment for students and instructors alike. This system, when fully realized, will support multiple domains, problem types that involve hand-drawn solutions, comprehensive feedback, multiple platform accessibility, and integration with other online course systems (e.g. Blackboard).

Approach
- To comprehensively address the current deficiencies of MOOCs, our platform, CourseSketch, will be designed using the following approach:

- **Review of the State-of-the-art:** To clearly distinguish CourseSketch from current solutions, our research project must include a thorough review of existing technologies, algorithms, and platform designs. After conducting our paper reviews, the relevant, existing solutions will be improved and integrated with our platform.

**Limited Feedback > Rubric/Recognition Integration:**
To enable personalized feedback, our system will use a robust sketch recognition platform that works in near-real time. We will design the system to intelligently integrate the sketch recognition technology with the instructors’ rubrics to generate relevant and timely feedback to the students (Figure 2).

**Limited Question Types > Sketch Recognition/Domain Expert Advice:**
To support problems that involve hand-drawn solutions, CourseSketch will harness robust sketch recognition technology. This technology needs to be designed to support all the user sketch inputs (e.g. shapes, characters, mathematical equations, etc.) relevant to the supported question types. Domain experts (e.g. professors, engineering students, etc.) will be consulted to determine what question types should be supported that online courses would benefit most from.

**Limited to Specific Domains > Robust Algorithms and Platform Design:**
The CourseSketch platform will initially support the domains of engineering statics, chemistry, and Japanese kanji. To be a multi-domain platform, we will develop robust parsing algorithms to transform all user inputted sketches into computer recognizable objects that the system can then automatically grade. For example, for statics, the system should detect a valid truss; or for chemistry, the system should detect a valid Lewis dot diagram. Each algorithm should recognize multiple equivalent drawings to be equally acceptable (Figure 3).

Limited Feedback > Rubric/Recognition Integration:
To ensure that the algorithms are robust, user studies will be conducted using the Sketch-based Online User Study Applet (SOUSA). Using SOUSA, we will gather statistics on how a given type of problem is generally solved and how the many of the variations of correct answers can be drawn.

Comprehensive Platform Design:
The following modular platform design enables future support of new domains:

**Front End:**
- Provides a simple and intuitive interface for the user to sketch their solutions and receive immediate and pertinent feedback

**Middleware:**
- Handles all the information transactions between the Front End and Backend including delivering the processed feedback that the system analyzed from the user’s sketch

**Backend:**
- Maintains a database which stores all the needed, persistent data for both the instructors, students, and courses and manages user registration and security

**Domain Specific:**
- Isolates domain related components to streamline adding future domains

Conclusion
The CourseSketch platform employs the use of multi-domain sketch recognition technology to allow homework submission through digital sketch interfaces. The sketch recognition technology allows for the automatic assessment of the correctness of a student’s hand-drawn solutions against the instructor’s. Instructors are able to build customized solutions for each assignment. The delivered platform is designed to work with multiple domains and is extensible to other domains. Because of the sketch recognition works in near real-time, students can receive personalized and immediate feedback on their progress on an assignment. The powerful automatic grading system eliminates the uncertainties found in the crowdsourcing method, and because the grading system is near real-time, it is increasingly difficult for students to cheat on their assignments. Our solution provides a reliable and accessible platform which relieves the grading burden from the instructors and teaching assistants so that they can focus their time and energies on engaging students. Our project group has completed much of the prior work research and are optimistic about the aforementioned results from our future platform testing.

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Results
**Sketch Recognition/Domain Expert Advice:**
- From the discussions our domain group has had with AME professors, the initial problem types for the domains are as follows: Truss problems for engineering statics, Lewis Dot diagram problems for chemistry, and single character problems for Japanese kanji.

**Results Evaluation Procedure:**
- Our pilot platform has been completed and is online. The robustness, correctness, and usability of our platform pilot were tested in both software unit tests and a controlled experimental group test.

**Unit Tests:**
- All the platform functions and algorithms built thus far have been tested within our project group. Our project team has the technical and domain expertise to evaluate our pilot to ensure the technical objectives have indeed been met by our platform pilot.

**Controlled Experiment Results:**
- From our survey, the users preferred the system’s evaluation better than their own. All the users strongly enjoyed the overall experience and would be willing to use the system in the future.

References