

YOJ: An Online Judge System Designed for Programming Courses*

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Abstract – Programming involved courses are difficult for most students, especially for novice programmer. To master computer programming, students need to understand abstract concepts and basic programming method, programming language, have problem-solving ability, and even more important is to do plenty of programming practices. This paper describes our online judge system (YOJ) which is used to support the teaching of the programming courses, making students to practice programming independently and helping teachers to assign homework on key programming concepts. Although YOJ is initially designed for our introductory programming methodology course (CS1), it can be easily adapted to support other programming courses.

Index Terms—Online Judge, pedagogy, computer programming.

I. INTRODUCTION

“Programming-first” approach is widely used for introductory computer science [1]. We offer the course of *an introduction to programming* to freshmen in their first semester. However, many students complain that this course is not an easy subject to be studied, especially for those who have no any experience on computer programming even never use computer. It is shown that the most difficult issue in programming is to understand how to design a program to solve a certain task, and the practical learning situations were the most useful [2]. Students need practical experience to understand the concepts and to develop computational thinking [3] which is quite different from other ways of thinking trained from childhood, but very important for learning programming. Paperwork cannot guarantee learning programming, and real learning only takes place when students doing programming practices. Therefore, a certain amount of effective programming exercises is the key to learn programming well.

Inspired by programing experts who have done a large number of online programming problems to improve their programming ability and prepare to attend ACM-ICPC International Collegiate Programming Contest [4], we believe that online judge system is worth using in our course. Therefore, Youxue Online Judge system (YOJ: <http://202.112.113.8>) is designed to support students practicing programming independently. Unlike the common online judge systems [5,6,7] which mainly provide problems, real-time evaluation and feedback, we carefully design YOJ system to support classroom teaching, which not only inspect whether students can solve certain problems correctly but also examine students’ understanding of some basic concepts.

This paper presents our online judge system (YOJ), which provides students with common online systems’ functions, such as do programing exercises any time anywhere, get feedback in real time and forum for discussing problems, but also support teachers to assign homework on specific knowledge and make sure that students have grasped them. Besides online problem, students can upload other forms of homework to YOJ, and the uploaded homework can be evaluated by a teacher or other students. Although YOJ is initially designed for our introductory programming methodology course (CS1) [8], it can be easily adapted to support other programming courses.

The organization of the paper is as follows. Section 2 gives an overview of YOJ system. Section 3 describes the use of YOJ system in the course of *introduction to programming* in detail. Section 4 introduces the use of YOJ system in other programming courses. Conclusion and future works are given in section 5.

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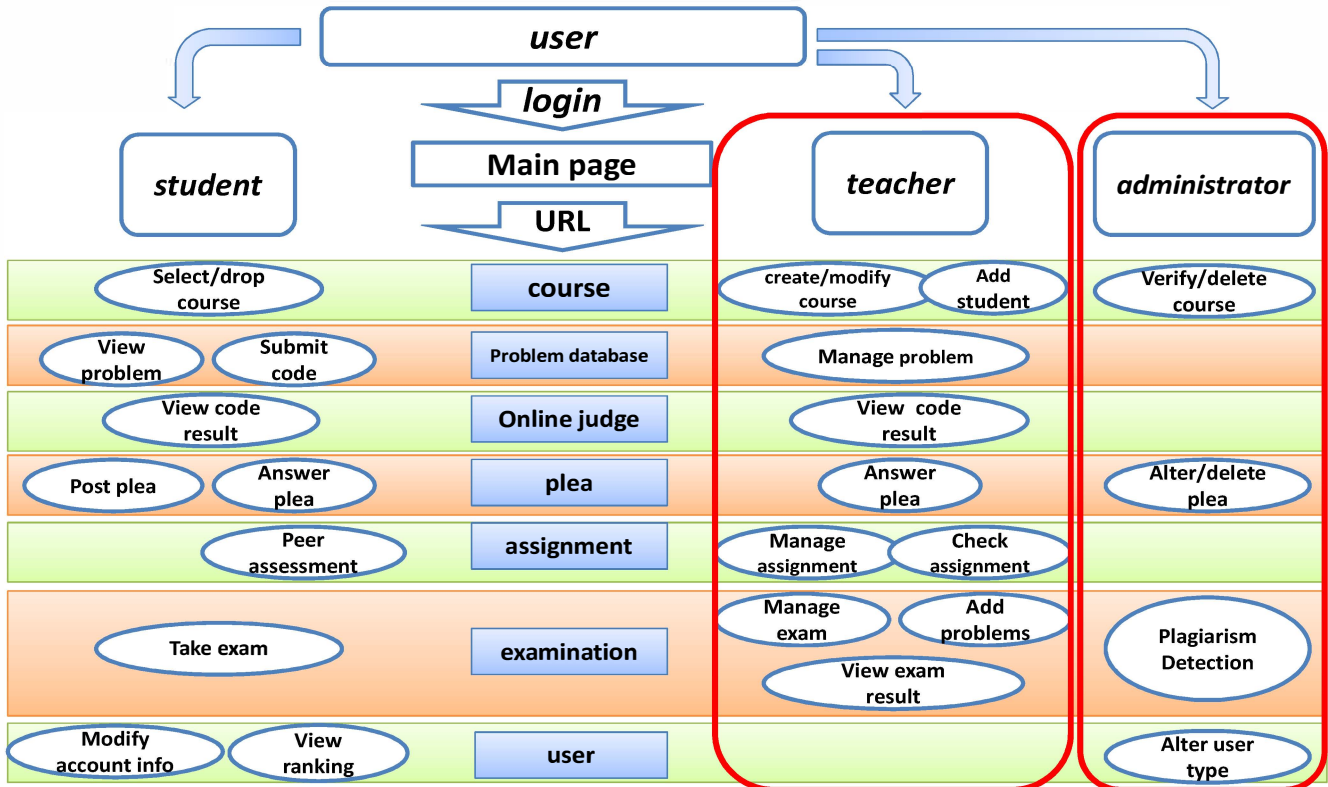


Fig. 1. The architecture of YOJ system

II. OVERVIEW OF YOJ SYSTEM

Unlike the common online judge systems such as PKU online judge system [5] which are problem-centered, our YOJ online judge system is based on the courses, whose main purpose is to support classroom teaching. YOJ system provides much more features to facilitate the understanding of programming abstract concepts and basic programming methods. We also put great emphasis on YOJ system's scalability and make sure the system can be easily used by other programming involved courses, such as data structure, algorithms and parallel Computing.

Figure 1 shows the architecture of YOJ system. As shown in the blue background boxes in middle of the figure, there are seven modules in this system, namely, the course module, the problem database module, the online judge module, plea processing module, offline-homework assignment module, examination module and user management module. The function of each module is described as below.

1) *Course Management Module*. As mentioned earlier, YOJ system is course-centered, in other words, all the activities in YOJ system are based on courses. The teacher must create a new course to use the YOJ system. In this module, a teacher can set up the homepage of the course, manage the course's information and courseware, and add students' account into the course. Then he/she can assign online problems or offline homework for the students in the course. The students can also decide to select or drop one course anytime.

2) *Problem Database Module*. All the online problems that users can do anytime anywhere and get feedback in real time are managed in this module, and teachers can set many attributes for each problem, such as test data, evaluation approach setting, etc.

3) *Online Judge Module*. Online judge module is the initial idea and the core component of the whole system. The module is responsible for compiling users' code, controlling the execution of users' programs, evaluating users' results and giving feedback. Commonly used online judge systems [5,6,7] only pay attention to whether the problem is correctly solved within a given time, but do not care how and in which programming language the problem is solved. In other words, these systems only care if you can design an algorithm to solve the problem correctly. However, for the course of an introduction to programming, teachers are concerned about more than just algorithm, such as programming concepts understanding and application, different implementations and so on. In order to meet the needs of the course of *introduction to programming*, this module allows users to submit their code in two different ways, namely, submitting all source code or only the part of the code such as one function, which makes YOJ quite different from other popular online judge system [5,6,7]. Allowing students submit part of code supports to examine students' understanding of specific knowledge taught in the classroom and make it possible to adapt YOJ system to other programming involved courses, such as data structure, parallel computing, etc.

4) *Plea processing module*. YOJ system allows users to discuss around a certain problem. Students can ask questions about a problem, and teachers and other students who have correctly finished this problem can answer the pleas. This

module also has a set of standards to reward the students who are willing to help others by answering question.

5) *Offline-homework Assignment Module.* This module allows teachers to assign offline-homework, such as document homework, and students can upload their homework before the deadline. It is worth mentioning that YOJ system allows students to evaluate other students' offline-homework in their group, which is conducive to learn from each other and reduce cheating.

6) *Examination Module.* We use YOJ system to do online programming contest with the support of examination module. To be specific, this module allows the teacher to setup a contest and adds problems into a certain contest in advance. The contest is not visible to students until the predetermined time, and students should finish the contest before the end time, any submission after deadline will not be included in the test scores. Another important feature of examination module is to monitor user accounts' activities, for example, the same user logins from multiple terminals is not allowed, and so do multiple users login from a single terminal. Plagiarism detection is also implemented in this module, which can find similar codes from different users through a specific algorithm. The feature of plagiarism detection plays an important role on avoiding plagiarism and establishing a good culture of learning.

7) *User Management Module.* Users manage their personal information here. There are three types of users in YOJ system, namely, ordinary user, teacher and administrator. Different users have different privileges.

a) *ordinary user:* Ordinary user can submit online problems and offline-homeworks, and discuss problems with each other.

b) *teacher:* Teachers can assign homework, provide online problems and organize contests in YOJ system. Teachers have the permission to view students' submitted codes, check their offline-homework and evaluate them.

c) *administrator:* Besides the privileges the teacher users have, administrator can change the type of a certain user and also take charge of confirming teacher's request of setting up a new course.

Above all, YOJ online judge system is carefully designed to serve the classroom teaching, which not only have common features that popular online judge systems [5,6,7] have, but also can be used to examine students' understanding of the abstract programming concepts. What's more, YOJ system is extended to support offline-homework submission and peer assessment.

III. YOJ IN COURSE OF INTRODUCTION TO PROGRAMMING


The course of introduction to programming [8] is the first professional course for undergraduate students major in our information school, which is offered in their first semester. This course focuses on training of the computational thinking, emphasize the basic programming concept, idea and method, and stress problem-solving ability. To achieve above teaching objectives, programming practice must play an important role.

Students need enough practical experience to understand the concepts and to develop computational thinking. We begin to use YOJ system since 2012, before that we use an open version of POJ [5] which cannot satisfy every requirement of the course, for example, it is hard to force students to use pointers to solve a certain problem because there is always a way to avoid using pointers.

Next, we describe the application of YOJ system on this

```
#include <stdio.h>
#include <stdlib.h>
#define nSize 30

typedef int ROW[nSize];

// please complete the function
// to do matrix transpose and output result matrix
void transpose( ROW *ary, int n, int m )
{
    
}

int main()
{
    int n, m, i, j;
    int matrix[nSize][nSize];

    scanf( "%d%d", &n, &m );

    for ( i = 0; i < n; i ++ )
        for ( j = 0; j < m; j ++ )
        {
            scanf("%d", &matrix[i][j]);
        }

    // do matrix transpose and out the matrix
    transpose( matrix, n, m );
    return 0;
}
```

Fig. 2 An example problem to inspect pointers

course from three aspects.

A. Inspect students' understanding of abstract concept

With YOJ online system, we can design problems to investigate each programming concept such as recursion, struct type, pointers, files, etc.

The above figure gives an example of an online problem, which require students to do matrix transpose. The teacher already givens some code, and students must complete the provided code, namely fill in a few lines of code in the blue background box. Unlike submitting their own code, to fill in the code, students have to understand the provided code especially any details about function definition. In other words, if a student cannot know the meaning of the variable "ary", he/she cannot make this problem solved. In this way, we can find whether students have grasped the concept of pointers and can make use of pointers, and of course they must understand the concept of function and function call. The same way, we can examine the students' understanding of arrays, files, recursion and other basic concepts of computer programming.

Students will benefit a lot from doing these carefully prepared problems which are targeted to help to understand abstract programming concepts.

B. Online contests

Online contests are very helpful for improving programming skills. Actually, the result of the online contests has a large proportion in final course grade. YOJ system provides good support to online contest, which can control the start time and end time of a contest and rank according to the contest scores.

What's more, the examination module of YOJ system has three highlights.

- First, YOJ system does a good job on monitoring students' login and logout activities which helps to avoiding cheating. Teachers can easily find if any one login with other's account.
- Second, for the codes submitted by students during the contest, there is a process of plagiarism detection which can screen out some suspicious similar codes. Plagiarism detection contributes to reduce the attempt of code copy.
- Debugging is always hard for novice programmers, especially when they do not know which test case makes their program broken. If the test case that their program can pass is provided, it will be much easier for them to fix the bug. Though, during the contest, YOJ system can be arranged to provide up to two groups of test data which break students' program, while normally all the error test data is provided.

C. Track students' learning progress

YOJ system has a certain amount of problems, whose quantity is much bigger than that the students are required to do. In other words, besides textbook, YOJ system is enough for students to learn the course of introduction to programming well, and they do not need to find other supplementary materials. Based on the above assumptions, we can easily track students' learning progress by checking their status in the system. For example, we manually analysis data of some students whose rank are among the last 5%, and the result shows that these students are lack of programming practice: most of them have little submissions in YOJ system, while others do have an amount of submissions, but most of the successful submissions happened in a very short period of time and without any debugging. These abnormal pattern hints that it is doubtful that if they submit their own code.

By analyzing students' data on YOJ system regularly, we can detect students' problems on learning in time and take actions.

IV. YOJ IN COURSE OF PARALLEL COMPUTING

YOJ system plays an important role on the teaching of the course of introduction to programming. It can be also helpful in other programming involved courses.

This semester, we try to use YOJ system in course of parallel computing. Erlang programming language [9] used in

this course is not a problem for YOJ or any other online system, but we need to expand YOJ system to run and evaluate parallel programs.

In order to evaluate the parallel efficiency of students' program, we need to run the students' program twice: one is a single process execution and the other is a multi-process execution, namely parallel execution, and then compare the running time of two executions. To achieve this, YOJ system needs a little improvement.

- First, online judge module of YOJ system should be separated from other modules of the system and run independently, maybe even in different computers, so a program can be executed in parallel on several online judges deployed in different computers. Now the online judge module is running on a dedicated computer and not have to give the evaluation result in real time because some parallel programs need few seconds, couples of seconds, dozens of seconds or even more to finish due to the problem's large-scale.
- In parallel computing course, YOJ system requires students to submit one or several functions instead of the complete program code. With a student's submitted function, YOJ system generates a new code which calls the submitted function twice, once for single-process execution and the other for multi-process execution. This new code also records running times of submitted function's execution and output the ratio of two running times which indicates the parallel efficiency.

With the above two improvements, YOJ system fully satisfies the needs of the course of parallel computing.

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we describe our YOJ online judge system which is used to support the teaching of programming involved courses. Besides the common features in popular online judge system, YOJ system pays more attention to examine the students' understanding of basic and abstract programming concepts. With the help of YOJ system, teachers can easily assign online problems to let students practice on hard concepts in programming such as recursion, pointers and references, function and so on. YOJ system also has good support to online contests.

As mentioned in section 3, we can track students' learning progress by analyzing students' data on YOJ system. It is a pity that we only analysis this data by hand now. In the future, we want to do some automatic analysis on students' submission records.

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