

Development of Autograder For Competitive Programming Using Contestant PC As Worker

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Abstract—Competitive programming is a computer science competition where the contestants compete to solve computer science problems by writing a program which satisfies the problem constraints. Autograder is used to grade contestant solutions automatically in real-time. Usually autograder is deployed in many computers to increase grading performance. In this work, contestant computers are used as worker to run autograder. By using contestant computers as worker, the number of worker will be proportional to the number of contestant submissions, thus increasing grading performance. Every contestant computer has different specification and can affect grading fairness. To keep grading fairness, contestant's solution and jury's solution executed in contestant worker and compared to check whether contestant's solution satisfies problem constraints. This work tested by simulating grading process in contestant computers. The testing result indicates that using contestant computers as worker gives performance improvement in the grading process.

Index Terms—competitive programming, online judge, autograder.

I. INTRODUCTION

Competitive programming is one of the most popular competition in computer science field. In competitive programming competition, contestants are asked to solve computer science problems correctly and as fast as possible. Some institute and organization often organize competitive programming competition periodically. Some big companies like Google and Facebook organize competitive programming competition annually. Competitive programming competition supported by online judge system. Usually, online judge system is a web based application where contestants can read the problems, create clarifications, submit their solution, and watch the scoreboard. Currently, the most popular online judge are Codeforces, URI Online Judge [8], Uva, and SPOJ.

In order to grade contestant submissions, online judge system has a subsystem called autograder. Contestant submissions which are source code in certain programming language will be graded by autograding system by compiling the program and executes compiled program using test-cases that have been prepared by juries or problem setter. According [14], this grading method is called black-box grading. By using autograding system, the grading process can be done automatically and juries don't have to evaluate contestant submissions manually. In order to increase the number of contestant submissions in certain amount of time, juries usually deploy autograder

in many computers. In order to run autograder in many computers, the juries need to prepare many computers with the same specification to keep the fairness of grading process.

Currently, almost every competitive programming competition use online judge system to support the competition and use many computers to run autograder in order to improve grading performance. Every computer that runs autograder is called worker. Grading performance is defined as the number of submissions graded in certain amount of time. Even though autograder is deployed in many computers, the grading performance is often not enough to evaluate contestant solutions in real-time because the number of contestants is increasing. Furthermore, the number of computer to deploy autograder affects the procurement cost that juries need to be incurred. Therefore, a new grading system is needed to increase grading performance without increasing procurement cost that needs to be incurred.

When competing in competitive programming competition, the contestants usually use their personal computer to write the solutions. Every contestant computer usually has sufficient specification to compile and execute contestant submissions. Therefore, contestant computers have the ability to run autograder program and evaluate contestant submissions.

II. RELATED WORK

There are some popular online judge systems that have been used to organize competitive programming competition. Some online judges offer additional features like discussion forum, training gate and rating system. Nowadays, most of online judges are deployed as web applications and use specific computers to grade contestant submissions. There are many types of competitive programming competition rules. Most of online judges only support specific competition rules.

One of the most popular competitive programming competitions is ACM-ICPC competition where the competition uses ICPC rules. In ACM-ICPC competition, contestants compete in groups of three people. Every group has the same amount of problems to solve, and the score is determined by the number of solved problems and time penalty. There are many online judges that support this competitive programming rules. The most popular online judge that supports this type of competition

is DOMJudge. DOMJudge is very popular because it has many usefull feature, easy to use and open source.

Currently, most of online judge use autograder to evaluate contestant submissions. According to [11], autograder is a system that compiles, executes and evaluate source code. Evaluates source code manually takes three minutes while using autograder only need ten seconds. By using autograder, contestants can receive grading feedback faster and reduce the work that need to be done by juries. Basically, the autograder evaluate the source code by compiles the source code, and executes the compiled program using predefined test-cases. The output of contestant's solution program compared to the predefined test-case and then graded. This evaluation method is called black-box grading [14].

We need to consider security aspect when developing autograding system. Competitive programming contestants might submit source code that contain dangerous code. According to [9], there are several attacks that can be made by contestants, such as submitting compile bomb code, submitting code that destroy autograding environment, and submitting code that access forbidden computer's resource. In order to prevent such things, autograding system must execute contestant's code in isolated environment called sandbox.

There are several ways to create isolated environment such as using virtual machine and containerization. By using virtual machine, one can create isolated operating system inside host computer. Virtual machine uses hypervisor to emulate computer hardware and run its own operating system. In Linux based operating system, there is a feature called KVM that make it possible to create hypervisor as a process in Linux [10]. We can use virtual machine to isolate the execution of contestant's code. However, by using virtual machine, we need to boot a new operating system each time we evaluate contestant's subission. This booting process takes so much computer's resource and reduces grading performance.

Another way to create isolated environment is by using container. Container is different from virtual machine. Container gives isolation in software level without hypervisor [12]. By using container, we can isolate process execution without boot a new operating system. Container works by using some Linux features such as chroot, namespace and cgroup. By using chroot, we can isolate filesystem of Linux process [13]. Container uses Linux feature called cgroup to limit process resources. By using cgroup, we can limit memory usage, CPU usage and disk IO usage of running process [10]. In order to hide other process, user, and network from a running process, container uses a Linux feature called namespace. By using namespace, we can isolate a Linux process from other process, so the running process not aware of the existance of other process. Instead of virtual machine, most of autograding system use container to isolate grading process. This method is used because it is more lighter and faster than virtual machine.

III. METHODOLOGY

A. Time and Memory Measurement

In competitive programming competition, every problems has time and memory constraints. Contestants are asked to solve the problem by writing program that satify the constraints. According to ICPC rules, when contestant's solution exceeds the problem constraints, the solution is rejected and the contestant get time penalty. Thus, autograding system need to tell whether contestant's solution exceeds the constraints or not. The problem is, every computer has different performance when executing a program. The same program might run faster in one computer and slower in another computer. Currently, most of online judge system uses identical computer to evaluate contestant submissions. By using identical computer, the same program expected to run at the same duration and consume the same amount of memories.

Contestant computers have different specification and performance. We cannot force the contestants to have identical computer. Thus, we need new time and memory measurement method. The performance of a computer is determined by its specifications such as CPU clock speed and operating system. We can tell the computer performance by its specifications. However, besides CPU clock speed and operating system, there are so much other factors that affect computer performance such as temperature, cache size, the program itself, and many other factors. Thus, determining computer performance by its specification is very hard and not feasible to do.

$$R_{contestant} < (1 + \gamma) \times R_{jury} \quad (1)$$

In this work, we compare contestant's solution and jury's solution. Contestant's solution considered satisfying the problem constraints when the memory and CPU usage of contestant's solution not exceeding jury's solution. Sometimes, contestant solution's memory or CPU exceeds jury's solution a little bit because the implementation is different. We add tolerance factor (γ) to tolerate this problem. Contestant's solution is considered satisfying problem constraints when the Equation 1 is fulfilled. When evaluating contestant's solution, the worker compiles and executes contestant's solution and jury's solution. After executes the solutions, the worker compares the memory and CPU usage of the execution and determine whether the contestant's solution satisfy problem constraints.

B. Load Balancing

C. Evaluating Submission In Isolated Environment

D. Program Compilation

E. Obtaining Problem Testcase

F. Handling Reverse Engineering Attack

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections III-G–III-K below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads— \LaTeX will do that for you.

G. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

H. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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I. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \quad (2)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(2)”, not “Eq. (2)” or “equation (2)”, except at the beginning of a sentence: “Equation (2) is . . .”

J. \LaTeX -Specific Advice

Please use “soft” (e.g., `\eqref{Eq}`) cross references instead of “hard” references (e.g., (1)). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don’t use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

Please note that the `{subequations}` environment in \LaTeX will increment the main equation counter even when there are no equation numbers displayed. If you forget that,

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\LaTeX does not have precognitive abilities. If you put a `\label` command before the command that updates the counter it’s supposed to be using, the label will pick up the last counter to be cross referenced instead. In particular, a `\label` command should not go before the caption of a figure or a table.

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K. Some Common Mistakes

- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
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- Do not use the word “essentially” to mean “approximately” or “effectively”.
- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
- Do not confuse “imply” and “infer”.
- The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the “et” in the Latin abbreviation “et al.”.
- The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

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Headings, or heads, are organizational devices that guide the reader through your paper. There are two types of headings: section headings and text headings.

Component headings identify the different components of your paper and are not topically subordinate to the main heading. Examples include Acknowledgments and References. For these, the correct style to use is "Heading 5". For figure captions, use "Caption" for your Figure captions, and "Table Caption" for your Table captions. Run-in headings, such as "Abstract", will not apply a style (in this case, italic) in addition to the text.

Text headings organize the topics on a relational basis. For example, the paper title is the primary heading because all subsequent material relates and elaborates on one topic. If there are two or more sub-topics, a second level heading (uppercase Roman numerals) should be used. Conversely, if there are not at least two sub-topics, subheadings should be introduced.

N. Figures and Tables

a) *Positioning Figures and Tables:* Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables should span across both columns. Figure captions should be placed below the figures; table captions should appear above the tables. Figures and tables should be cited in the text as "Figure 1" or "Table 1", even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

^aSample of a Table footnote.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of

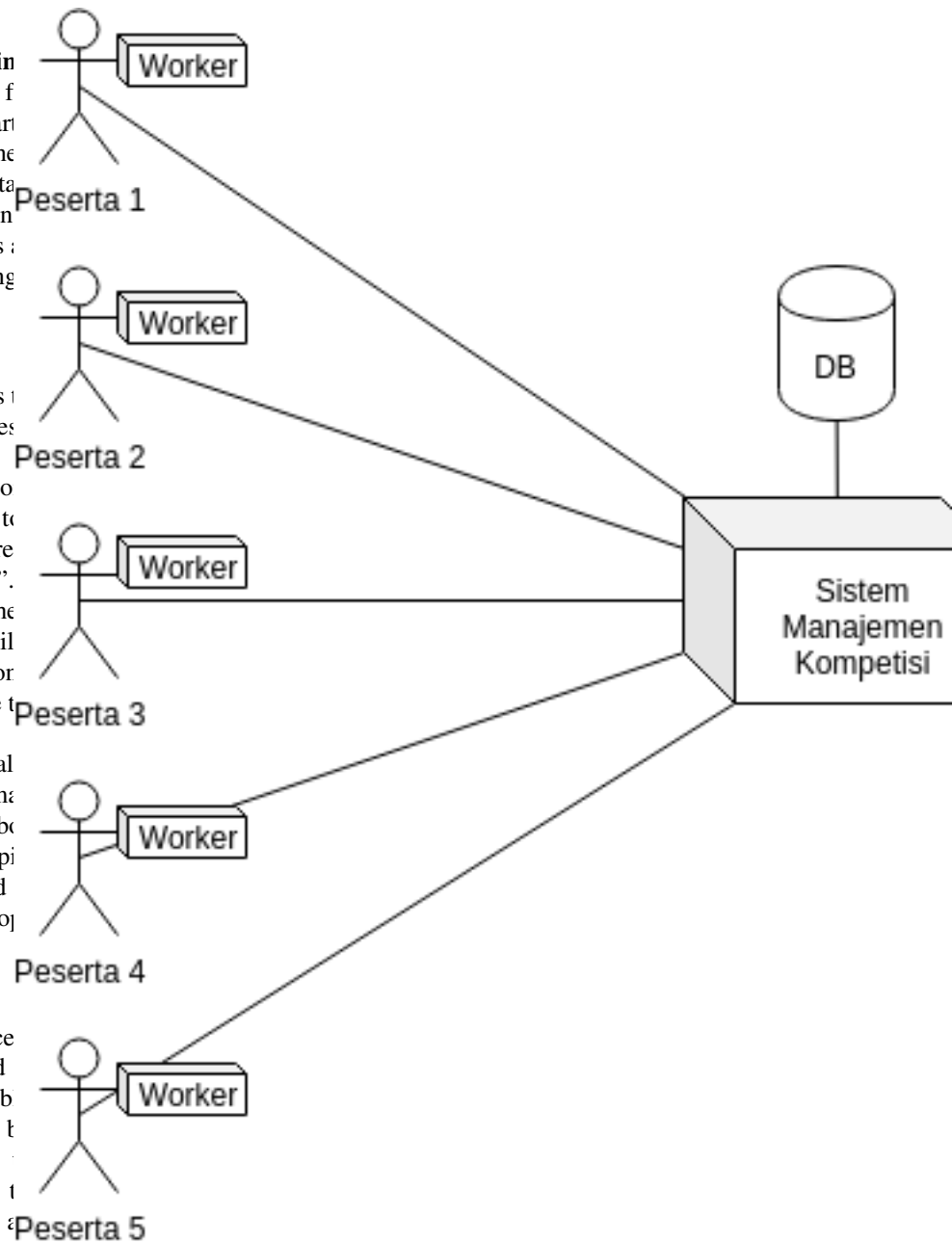


Fig. 1. Example of a figure caption.

quantities and units. For example, write "Temperature (K)", not "Temperature/K".

ACKNOWLEDGMENT

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Please number citations consecutively within brackets [15]. The sentence punctuation follows the bracket [16]. Refer

simply to the reference number, as in [17]—do not use “Ref. [17]” or “reference [17]” except at the beginning of a sentence: “Reference [17] was the first . . .”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [18]. Papers that have been accepted for publication should be cited as “in press” [19]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

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REFERENCES

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- [2] TODO.
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