Chapter 2 & Chapter 3

(This version is not the final version. It can be useful material for writing the final report. The order of material is meaningful.)

**[Classical programming learning ways (edit from the proposal)]**

Writing code, undoubtedly, is one of the core parts of the Science in Computing programme, and consequently, it is also the toughest part for learners, especially beginners. Students are not only required to have the ability to analyze the solving logic of problems, but also they need to be proficient in different coding syntaxes. In this case, students need to make many attempts to solve the programming problems, and they may easily give up during this period. To ameliorate this situation, two classical programming learning methods are introduced into the courses to improve students’ code-writing skills. Specifically, one of the methods is a preparation action for code writing, Coached Program Planning. This method guides students to analyze the problems and design the logical procedures with native-language style pseudocode for solving these problems [2, 3] so that the logical parts of codes can be partially separated from the syntax parts reducing the cognitive burden during coding to some extent. Another method is code tracing, which is to track the changes of variables by hand during the execution of codes [4]. Although this method does not have a direct effect on code writing and cannot be applied to every programming question because of its cumbersome procedure, it, through the accumulation of experience in code reading, still can provide some kind of auxiliary help in improving code writing skills.

**[Previous Parsons problem application]**

Besides the above two programming learning methods, a new way, Parsons problem, was created to prepare students for writing code [5]. Instead of letting students directly write code, Parsons problem provides a set of code fragments – including the solutions to the questions and some distractors (some common errors) - for students to choose from and reorder by dragging and dropping [5]. During this period, students can get some instruction feedback for their reordered answers, and they need to repeat reordering until their answers are one hundred percent correct [5]. This method provides notable help in introductory programming study. To be more specific, the puzzle-like game-style Parson problem can improve students’ engagement and motivation in learning programming [5]. And with prepared code fragments and instant feedback, the levels of difficulty of the questions are reduced, and students are more likely to persist in programming instead of giving up halfway. Besides, Parsons problem can be of use to reduce cognitive load since students are only required to reorder the prepared code fragments instead of writing code directly [1]. And some context (fixed code) also can be provided to students to reduce cognitive load further [6]. In addition, Parsons problem integrates the respective advantages of both Coached Program Planning method and the code tracing method. Specifically, Parsons and Haden picked up an idea to include activity diagrams in the questions’ descriptions to help students to understand the solution logic of problems [5], which has a similar function to Coached Program Planning method. And since Parsons problem also requires students to read and understand the meaning of every code fragment, it also takes advantage of code reading just like the code tracing method. In other words, Parsons problem provides magnificent solution examples for students to learn from, giving them some reference material to think about solution steps when meeting some similar questions. Finally, Parsons problem also has an effect on helping students to cultivate good coding habits. For example, the distractors in Parsons problem can be used to show some improper variable names, which assists students to distinguish good names from bad names and train the habits of using meaningful and conforming naming rules names [5].

**[The benefits of using Parsons problem in Data Structures and Algorithms courses]**

Although Parsons problem makes great success in teaching programming, it is limited to only being used in introductory programming courses, and it has not been expanded in middle-level programming courses, for example, Data Structures and Algorithms courses. ~~From my~~ ~~perspective~~, Parsons problem still can demonstrate its superiority in Data Structures and Algorithms courses. Admittedly, students taking intermediate-level programming courses should be able to write code instead of just rearranging the order of provided answer blocks. However, because of the abstractness and universality of programming in this course, it also is a challenging task for students to write it directly (for example, recursion problems). Thus, it is of the essence to introduce Parsons problem to build a “bridge” for students to grow their capability to write code directly by themselves. But, since there are some differences between introductory programming courses with Data Structures and Algorithms courses, the previous Parsons problem in introductory programming courses does not fit the situation in Data Structures and Algorithms courses, and it is not suitable to apply the previous Parsons problem directly. Consequently, some new ideas should be introduced to Parsons problem. The detailed difference between the two courses and the limitation of the previous Parsons problem will be discussed in the following paragraphs.

**[The difference between two courses]**

There are some major differences between introductory programming courses and Data Structures and Algorithms courses. To be more specific, the programming in introductory courses is simple and concrete. It only requires students to understand codes line by line. And most of the parts in this course are separated and not related so it is almost unneeded for students to compare the differences. By contrast, the programming in Data Structures and Algorithms courses is complex and abstract. It focuses on large block code understanding instead of line code understanding. Students are required to not only understand every line of code but also the specific data structures, the classes with their methods (Object Oriented Programming), the recursion methods for general use, and the algorithms with the corresponding analysis. Besides, there are more similar concepts needed to be compared, for example, stacks and queues, different types of trees, and different algorithms for the same purposes (like bubble sort and selection sort for sorting, and breadth-first search, depth-first-search for searching).

**[The specific question in Data Structures and Algorithms and the limitation of previous Parsons problem]**

The differences between introductory programming courses and Data Structures and Algorithms courses lead to the limitation of using the previous types of Parsons problem directly in the Data Structures and Algorithms courses.

To show the limitation in detail, five types of questions in Data Structures and Algorithms courses are summarized from the reference book Data Structures and Algorithms in Python

To show the limitation, we have analyzed the exercises in the book and identified five types of common questions.

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[7].

**[Object-oriented programming type of questions]**

Object-oriented programming is a programming model based on objects, which includes attributes and methods [8]. In CS1, since all the programming parts are Function Oriented Programming, the object-oriented programming concept has never been involved. However, in CS2, this concept becomes one of the focal points, since it is the foundation to build different data structures. Because of introducing the object-oriented programming concept, the previous types of Parsons problem cannot work as well as before. This is because the codes in a class look like tools in a tool chest, which means they are only used when doing specific work and the order of placing tools does not have a big effect on using tools. For this reason, the reordering function of previous types of Parsons problem is significantly weakened. Taking an example (Figure 1) [7], the methods in this CreditCard class are the tools to achieve some functions of a credit card, which means that these methods are only called when needed instead of being executed in sequence. Hence, changing the order of methods does not affect the program execution. And in this example, some methods only need one line to return some attributes so it is a piece of cake to guess the corresponding contents of the methods according to the names of the methods. Thus, in this code, only 12 lines instead of 52 lines are valuable to use Parson problem to reorder. It is evident from this example that the utility of the previous type of Parsons problem is watered down.

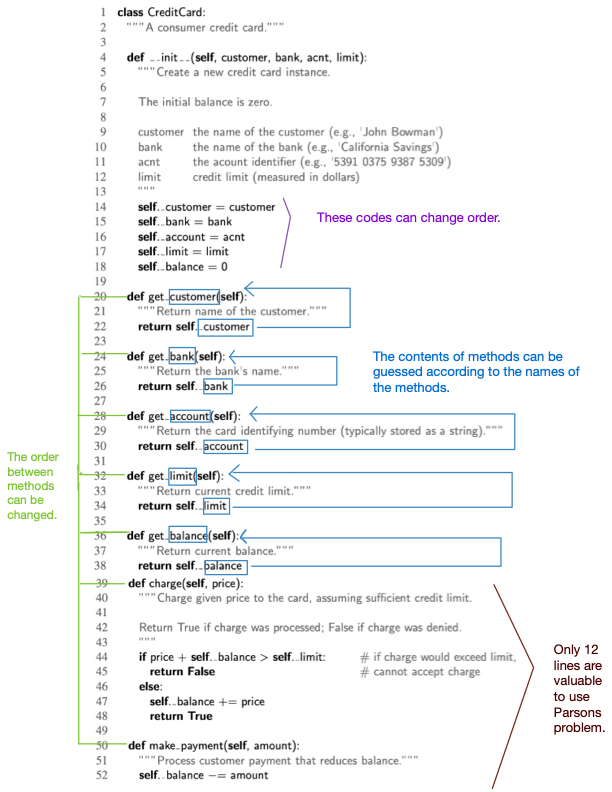


Figure 1 The object-oriented programming example code

**[Algorithm analysis type of questions]**

Algorithm analysis, which is a core part of CS2, is to use running time to evaluate whether a data structure or an algorithm is efficient or not [7]. Since the growth rate of running time as a function of the input size n is vital for algorithm analysis, big O, which shows the major parts affecting the growth, is introduced in algorithm analysis [7]. There are seven basic functions in big O (the constant function, the logarithm function, the linear function, the N-log-N function, the quadratic function, the cubic function and other polynomials, and the exponential function) [7] so it is strenuous to ascertain which functions are the correct functions to describe the efficiency of the specific data structures and algorithms. By contrast, the algorithm analysis in CS1 is much more straightforward since only three functions (the contrast function, the quadratic function, and the cubic function and other polynomials) are used and the functions used are only lying on whether there are loop structures or nested loop structures. For this reason, the algorithm analysis parts are always ignored in CS1 so the Parsons problem for CS1 certainty cannot handle this algorithm analysis questions, which is another drawback for using previous types of Parsons problem directly in CS2.

**[Recursion type of question]**

Recursion is to solve a problem by solving a subproblem that has the same structures as the original problem. In programming, it is achieved by calling the function itself, which means that the same code in a recursion question can solve the same problem but with different values of input parameters. This situation, one code holding different cases, is not common in CS1. For this reason, it leads to a dramatic increase in the difficulty of problems and the previous type of Parsons problem cannot have a significant effect on reducing complexity. Concretely, the previous type of Parsons problem reduces the level of difficulty by providing some code fragments for students to read. However, in the recursion type of question, it is arduous to understand the meaning of every line of code even if the whole code is given in order (like the recursion example code of the Tower of Hanoi in Figure 2 [9]). Thus, the assistance coming from code reading of Parsons problem is notably shrunk, and it is almost like letting students write code directly. That is why the previous type of Parsons problem needs to be improved to give students more hints in solving recursion questions.

Text

Description automatically generated

Figure 2 The recursion example code of the Tower of Hanoi

**[The data structure and algorithm types of questions]**

One of the characteristics of code in CS2 is similar to each other. For example, the codes can have the same data structures but are implemented in different ways (like the array-based stack and linked-list-based stack in Figure 3) or different solving algorithms for the same problems (like bubble sort and selection sort for sorting numbers problem). Although it is ok to use the previous types of Parsons problem individually for each code, it would be more worthwhile to help students to compare these similar codes and consolidate the difference and similarity between these codes. Therefore the students can distinguish them and have a better understanding.



Figure 3 The array-based stack and the linked-list-based stack

**[References]**

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