A Proposal for CS Unplugged Utilizing Regional Materials

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Abstract - This paper proposes CS Unplugged utilizing regional materials. CS Unplugged is a method of teaching computer related technology to children, who are in general lacking in mathematical or some other scientific background. The feature of CS Unplugged is that it does not use actual computers in its teaching process. Instead of using computers, it teaches computer related technologies through some desktop play activities. We propose those activities utilizing regional materials. When we practice CS Unplugged activities in elementary or junior high schools, the target pupils are local children in general. Using regional materials in the activities can make them more friendly to the children. In this paper we show the concrete example of activity that successfully utilizes the geographical feature of Matsue City to teach children the concept of computing bottlenecks. In this activity we regard the geographical feature of Matsue as one of its regional materials.[1]

Keywords: Computer Science Unplugged, Teaching Methods, Regional Materials, Bottlenecks

1 INTRODUCTION

The lack of interest in computer science among children has increased in recent years and the aversion of young people to enroll in information system curricula at universities is a growing problem. To reverse these trends, some means of making computer science fun to learn and easy to understand for children is essential.

One such means is Computer Science Unplugged (CS Unplugged), an educational method comprised of desktop play activities, such as board games and so on, without the use of computers [1]. In other words, children can learn computer related technology indirectly. We believe that it is an appropriate teaching approach to children, because they are so lacking in mathematical and some other scientific background that it is difficult for them to learn computer related technologies directly.

CS Unplugged has originally been proposed by Timothy Bell of University of Canterbury, New Zealand. According to the homepage of CS Unplugged, around 20 activities are already defined. Twelve activities of them have been translated into Japanese by Japanese researchers and published [2]. In Japan, the subject "Information" has been compulsory since 2003 in high schools and the subject "Measurement and Control by Programming" has been compulsory since 2012 in junior high schools. These trends mean the importance of teaching computer related technology to relatively young generation. Some junior high school and senior high school teachers have tried to apply the CS Unplugged approach in their classes and have reported their experiences [3][4].

Although it is a promising teaching method, the current CS Unplugged activities are considered to be inadequate in terms of the coverage of technologies. Some new activities corresponding to technologies that have not been addressed in the manner of CS Unplugged have to be developed. These new activities must be friendly to children in order for them to be effective.

When a CS Unplugged activity is practiced by the pupils in an elementary school or a junior high school, most of those pupils could be local children in general. In this sense, utilizing regional or local materials as the content of the activity is considered to be effective, because the children must feel familiar with it.

In this context we have developed the new activity in which children can learn the phenomenon of bottlenecks [5]. As far as we have investigated, there is no activity that deals with bottlenecks. This activity utilizes the geographical feature of Matsue City in Japan, which we regard as one of its regional materials. It is a two-player board game and through tackling the game children can understand the phenomenon of bottlenecks and learn how to avoid the occurrence of them. In the following sections we will show the details of this activity and also show the result of its practices by the children in a junior high school and a college of technology, both in Matsue City.

The rest of this paper is organized as follows. Section 2 describes the outline of CS unplugged. From Sections 3 through 5, the details of the newly proposed activity are shown. Section 6 presents the feedback from children. Section 7 deals with one of the future works with regard to utilizing regional materials in CS Unplugged. Finally, conclusions are drawn in Section 8.

2 CS UNPLUGGED

CS Unplugged is a method of computer science learning originated by many people, especially Tim Bell of the University of Canterbury in New Zealand, and currently includes around 20 activities as shown in Table 1. Each of these activities addresses a computer science concept that is taught in specialized courses at senior high school and college, but it is designed so that elementary and junior high school students can understand the concept while enjoying the performance of a game, magic trick, body movements, or other form of activity. The CS Unplugged activities are characterized by features such as the followings [6].

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Table 1: Activities in the Japanese-language teachers' guide

No.	Title	Concept
1	Count the dots	Binary numbers
2	Color by numbers	Image representation
3	You can say that again !	Text compression
4	Card flip magic	Error detection and correction
5	Twenty guesses	Information theory
6	Battleships	Searching algorithms
7	Lightest and heaviest	Sorting algorithms
8	Beat the clock	Sorting network
9	The muddy city	Minimal spanning trees
10	The orange game	Routing and deadlock in network
11	Treasure hunt	Finite-state automata
12	Marching orders	Programming languages
13	The poor cartographer	Graph coloring
14	Tourist town	Dominating sets
15	Ice roads	Steiner trees
16	Sharing secrets	Information hiding
17	The Peruvian coin flip	Cryptographic protocol
18	Kid Krypto	Public-key encryption
19	The chocolate factory	Human Interface design
20	Conversations with computers	Turing test
21	The intelligent piece of paper	Artificial intelligence

- Learning at play
- Learning by trial and error with concrete physical objects and bodily sensations
- Learning in groups
- Ease of execution
- Learning through interwoven story elements

A teacher's guide for CS Unplugged is publicly available and can be downloaded free-of-charge from the official CS Unplugged website [1].

A Japanese translation containing the first twelve activities of the activities shown in Table 1 was published in Japan in 2007 [2].

3 TARGET CONCEPT OF NEW ACTIVITY

The concept addressed in the new activity is computing bottlenecks [7]. It is believed to be a new activity, as a preliminary survey of the current CS Unplugged activities did not show the same concept.

3.1 Computing Bottlenecks

In computer science, a bottleneck acts as a constraint on communication via a medium that links two points and thus presents a barrier to increasing the processing speed of a computer or the communication speed of a network beyond that of the bottleneck itself. In von Neumann computers, von Neumann bottlenecks tend to occur because of the difference between the processing speeds of the CPU and the computer memory or because of insufficient width in the bus that links them. These problems limit or decrease the processing efficiency of computers.

Figure 1: Ohashi-gawa River vicinity in Matsue City

3.2 Geographical Bottleneck in Matsue City

Matsue City, where one of the authors' former campus is located, is in Shimane Prefecture, Japan. Its geographical features, and in particular its river-straddling configuration, are well suited for illustration and explanation of the bottleneck concept.

Matsue City lies in a region between two bodies of water called Lake Shinji and Nakaumi Lagoon, and its urban center is divided into northern and a southern district by the Ohashi-gawa River, which flows from Lake Shinji to Nakaumi Lagoon. The river is shown in Fig. 1. The northern district is called Kyohoku and the southern district is called Kyonan. Until the early Showa period, they were connected only by the Matsue Ohashi bridge. Today they are connected by the Shinjiko Ohashi, Matsue Ohashi, Shin Ohashi, Kunibiki Ohashi, Enmusubi Ohashi and Nakaumi Ohashi bridges. The Enmusubi Ohashi bridge, the latest one, was constructed in 2013 to relieve the congestion occurring in the traffic attempting to cross the older bridges during the morning and evening rush hours.

The proposed activity is a board game modeled on these geographical features of Matsue City and designed to help students gain a clear experience-based understanding of the bottleneck concept.

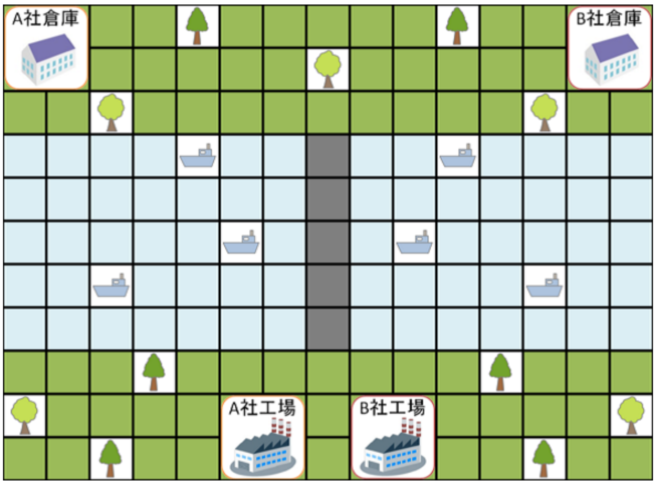
4 DETAILS OF THE ACTIVITY

4.1 Overview

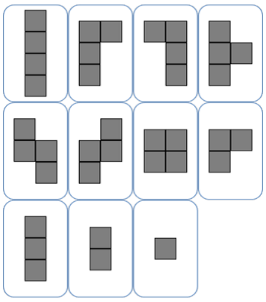
In this activity, two students compete against each other in a board game to see which one's pieces can reach the goal more quickly. The learning materials are the board and the pieces. In the game, they experience bottlenecks and devise strategies to relieve them.

4.2 Learning Materials and Rules

Figure 2 shows the following learning materials used in this activity: the board, eight pieces, and eleven bridge-building cards.



(a) Board



(c) Cards

(b) Pieces

Figure 2: Learning materials

4.2.1 Board

The board represents a city divided into north and south sides separated by a river, much like Matsue City. As shown in Fig. 3, the board comprises 165 squares (11 vertical and 15 horizontal) of six types, either singly or in combination, to represent the land, a river, one or more bridges, two warehouses, two factories, and twelve obstacles (trees and boats).

Each of the warehouses and factories occupies four squares. One warehouse and one factory belong to Company A, and the others belong to Company B. Before starting the game, the students choose between Company A and Company B. The student taking Company A makes the first move. For each student, the warehouse of his or her company is both the starting point and the final goal.

4.2.2 Pieces

Each student has four pieces, which represent trucks that transport production materials and products between the warehouse and the factory of his or her company. The students take turns, with each student moving all four of his or her pieces per turn throughout the game. Each piece can be moved just one space per turn. They start on the warehouse squares, with each piece representing a truck loaded with production materials. When a piece reaches the factory squares, it is turned over to represent a truck loaded with the products which, on the next turn, sets out for the company warehouse–the final goal.

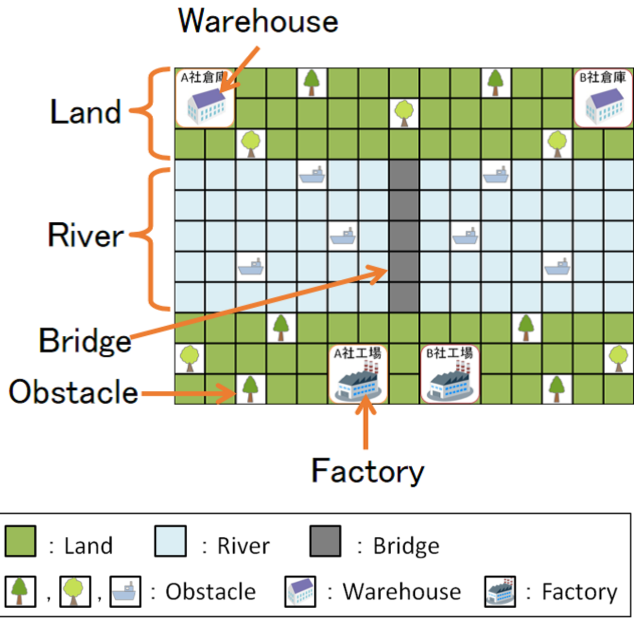


Figure 3: Board components

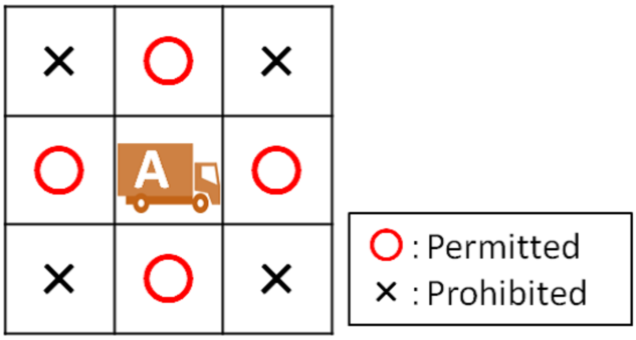


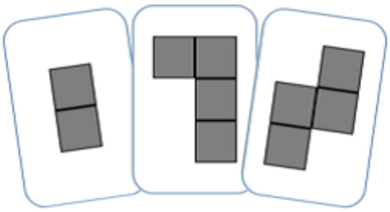
Figure 4: Permissible moves

As illustrated in Fig. 4, a piece can be moved from the square it occupies to a land, warehouse, factory, or bridge square on any of its four sides, but cannot be moved diagonally or onto any square representing the river, an obstacle, or the other student's factory or warehouse, nor to any occupied square other than those of the student's own factory or warehouse.

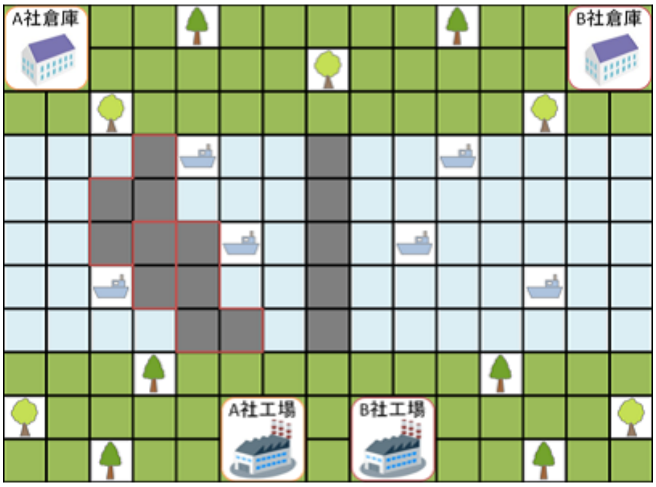
During one turn, the student must move each of the four pieces one space unless if all adjacent squares are already occupied or represent the river, obstacles, or the other company's facilities.

4.2.3 Bridge-building Cards

Each bridge-building card shows at most four squares arranged in a different block configuration, such as those shown in Fig. 2(c). Before the game, each student chooses three of the cards. During the game, when he or she cannot move any of his or her pieces, the student in turn may use one of his or her own cards to mark river squares in the same block form as



(a) Chosen cards



(b) A possible bridge configuration

Figure 5: Bridge-building cards and their usage

shown on the card. The pieces of each student can be moved to any bridge addition space marked by either student.

Assuming that a student chose three cards as shown in Fig. 5(a), one of the possible bridge configurations during the game can be shown in Fig. 5(b). In this case, the student has used a card three times.

5 TEACHING PROCESS

The overall process for the student experience and learning of the bottleneck concept begins with an introduction by the teacher, followed by playing a practice game and then the actual game by the students.

5.1 Introduction

The teacher first tells the students a story about the two adversarial companies, A and B, which are mutually competing to perform faster operations. For each company, the operations require the transport of production materials from its warehouse to its factory on trucks that must then transport the factory products back to the warehouse because they cannot be stored at the factory. In both cases, the warehouse and the factory are separated by a river that is currently spanned by only one bridge, and their trucks therefore cause traffic congestion in that area. In this way, the story provides the setting for the game.

5.2 Practice

After hearing the story, the students first perform a practice game without the bridge-building cards. The board therefore

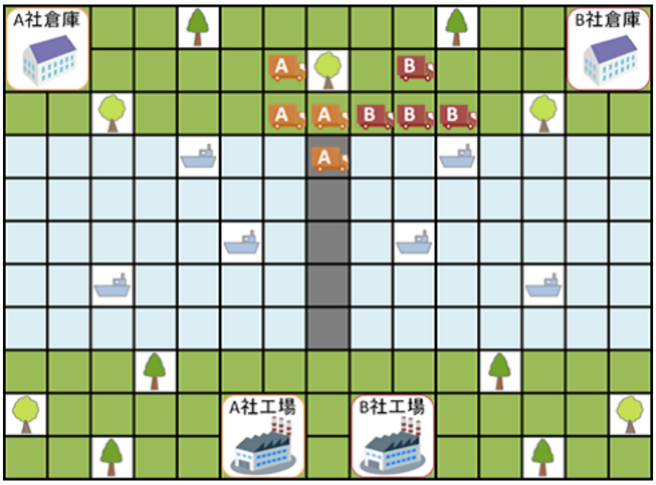


Figure 6: A traffic jam in the practice game

remains in its initial state throughout the game with no increase in bridge squares, as illustrated by the interim stage of the practice game shown in Fig. 6, in which the trucks of the two companies have caused a traffic jam as they attempt to move onto the bridge while driving toward their respective factories. In playing the practice game, the students gain their initial experience in the bottleneck problem in the form of traffic congestion at the bridge between the two land areas.

5.3 Game

After completing the practice game, the students next proceed to the actual game, with the use of the bridge-building cards to make bridge additions prior to the game itself. Figure 7 shows an interim stage of one such game. As the game proceeds, the students experience first-hand the effects of these bridge additions in relieving traffic congestion and enabling smooth progress toward the final goal.

In Fig. 7, the students have increased the number of bridges from one to three, which is comparable to the widening of a bus connecting CPU and memory to relieve a von Neumann bottleneck. These three bridges are basically single-lane bridges, but the addition of a ”siding” such as that in the center bridge enables trucks moving in opposite directions to pass each other, which was not possible on the original bridge.

The outcome of each game is governed largely by the width and shape of the bridge additions constructed by both students, which leads each of them to develop and try out various bottleneck mitigation strategies in successive games.

6 EXPERIMENTS

We conducted three experiments for the activity mentioned above. The specifications of these experiments are shown in Table 2. A snapshot taken in the third experiment is shown in Fig. 8.

From the first experiment through the third, the activity had been gradually enhanced. The primary enhancement was to give users more choices of tactics to win the game, such as increasing the number of pieces and card patterns and so on.

There were thirty four participants in total, and thirty two of them had not had any knowledge of bottlenecks before the

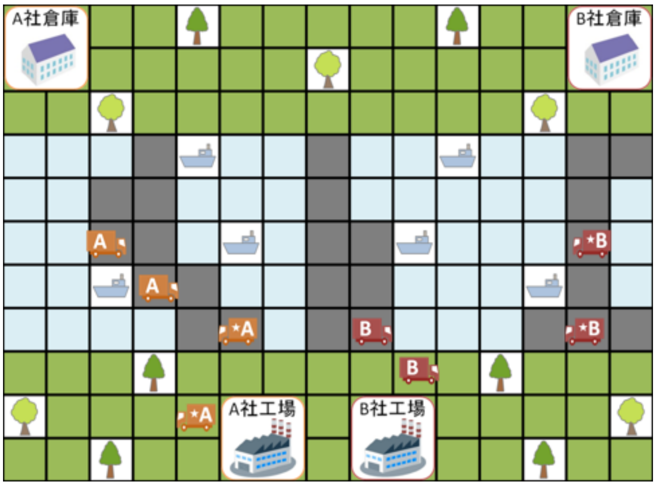


Figure 7: A game in progress with alleviated traffic congestion

Figure 8: Snapshot of the third experiment

Table 2: Specifications of three experiments

Grade	Number of children
First graders of college of technology (15-16 years old)	7
First graders of college of technology (15-16 years old)	19
First graders of junior high school (12-13 years old)	8

Table 3: Understanding level of participants

Did you understand what bottleneck is?		
Answer	Number	Percentage
Yes	24	71
Rather yes	8	24
Rather no	0	0
No	0	0
No answer	2	6

experiments.

After each experiment, a questionnaire was give to the participants. The aim of the questionnaire was to investigate the interest of the children and to determine if they understood the concept of bottlenecks. The most important question was "Did you understand what bottleneck is?" The children were given four choices for this question: yes, rather yes, rather no, and no.

Table 3 shows the result for this question. We did not have any negative answers. In addition, we observed that the children really enjoyed the activity and tackled it positively.

Although the scale of our experiments was small and we only obtained the subjective evaluations, we believe that the activity could be effective in learning the concept of bottlenecks.

7 FUTURE WORK

As for utilizing regional materials in CS Unplugged, we could take a different approach from the one described above. This approach replaces the content of the existing activities with some regional materials [8].

One example is Activity 2, in which children learn a run-length representation of images. Children learn how to transform given images to their run-length representation and vice versa. As those given images, we can easily introduce the images that represent some local materials. Figure 9 shows some examples. These images represent the materials local to Shimane Prefecture.

Another example is Activity 3, in which children learn data compression technique similar to Lempel-Ziv compression algorithm. In this activity, children are given some short sentences such as poems that have many repeated phrases. We can easily replace these sentences with the ones locally well known in some specific region, such as lullabies and folk songs.

We would like to take this approach as one of the future works for the study of utilizing regional materials in CS Unplugged, because its effectiveness should be confirmed through several experiments.

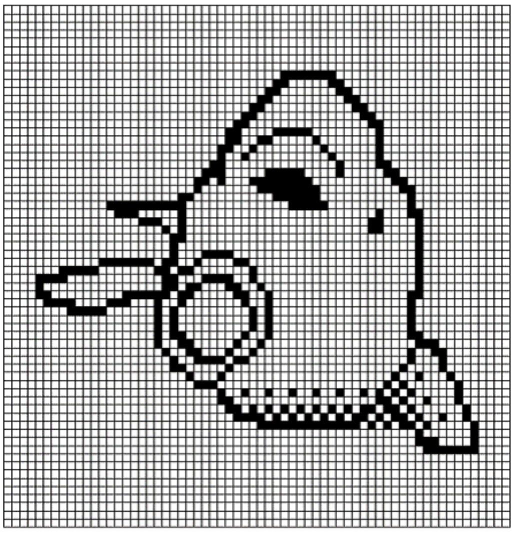
8 CONCLUSION

In this paper, we have proposed a new CS Unplugged activity utilizing regional materials. It has been designed to increase children's understanding of computer science through an enjoyable learning experience, with the ultimate objective of contributing to the increase of CS Unplugged adoption and use.

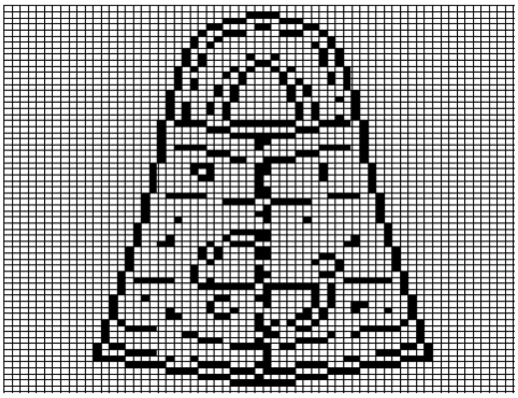
The target concept of the proposed activity is a computing bottleneck. For the learning experience, we designed a board game and materials in which the board is modeled after the geographical features of Matsue City, where one of the authors' former campus is located, and, in particular, on its bottleneck-inducing configuration.

In order to evaluate the activity, we conducted three experiments at a junior high school and a college of technology. The participants of the experiments showed their interest in the activity and gave us rather positive response in terms of understanding level of bottlenecks.

The cumulative results of the evaluations and trial-and-error modifications will be applied to the intended achievement of the activity in which children can learn the bottleneck concept



(a) White dolphine and bubble ring



(b) Dotaku(Bell-shaped vessel)

Figure 9: Images local to Shimane

more easily and enjoyably.

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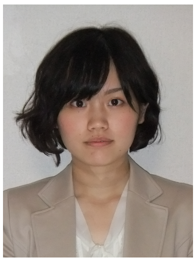

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