Approach toward the construction of
an automated tailor-made curriculum

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Abstract

Our research group has developed some e-learning programs mainly for Japanese college students to improve their English reading and listening skills; one is PREMA (your Personal REading MAnager) , a program for extensive reading, and another "your Personal LIstening Manager (PLIMA)" focusing on improving poor phonological analysis and the inability to hear liaison or unstressed sounds and so on. However, it is not enough to only point out the shortcomings of undeveloped learners, as they often have great difficulty choosing learning materials of the appropriate level. Therefore, we have started to consider an e-learning program that automatically selects appropriate-level exercises to learners through a mathematical approach. This paper investigates how we will be able to realize an automated tailor-made curriculum with making use of a mathematical approach called Mixed-Integer Programming.

Keywords: e-learning, optimization.

1.　　Introduction

PREMA (your Personal REading MAnager) is one of the e-learning programs we have developed, that allows online or offline texts to be used as extensive reading material, alleviating the need for libraries of graded readers (Hashimoto & Okazaki 2012). Another is "your Personal LIstening MAnager (PLIMA)" focusing on improving poor phonological analysis and the inability to hear liaison or unstressed sounds and so on (Okazaki, Nitta & Kido 2011).

In the current study, in order to maximize the learning effect within the limited learning time, we propose a mathematical approach that allows for the selection of learning materials (LMs) that will have the largest effect on improving the weakness of the student.

2.　　Method

Let us say that there is a student who would like to choose material to maximize their learning from among those introduced during the course of one semester, supposing that one semester is made up of fifteen 90-minute classes. The first step is for that student to take a listening diagnostic test which identifies weaknesses in their learning, such as difficulty in hearing liaison sounds, reduction, or elision. The database of the e-learning program is programmed to track the various sound elements such as those mentioned above. The system then selects LMs that contains those sound elements that the learner has the most difficulty with. This selection process is realized by a mathematical approach called Mixed-Integer Programming. This mathematical approach allows for the selection of LMs that will have the largest effect on improving the weakness of the student within a given time frame.

2.1.　　Learning material selection problem

Problem settings are as follows :
- Multiple LMs can be employed.
- Each of the LMs contains leaning elements (LEs). The LEs include features such as phonological liaison sounds, reduction, elision, etc.
- Learning time for each of the LMs is set.
- A diagnostic test is used to identify weaknesses in learners such as difficulty in hearing liaison sounds, reduction, or elision.

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- It is posited that when a learner uses a highly-evaluated LM that contains a certain LE, the leaner's ability of the element goes up.

2.2. Formulation

We will formulate the LM selection problem by means of applying a typical formulation of the Knapsack Problem. The Knapsack Problem refers to a situation where we try to maximize the sum of the values of a given weight or volume capacity.

Sets, variables, and constants are as follows:
- Sets
  $i \in M$: set of the LMs
  $j \in N$: set of the LEs
- Constants
  p_j : the correct answer rates of the questions about LE j in the first diagnostic test
  r_j : the appearance rates of the questions about LE j in the past tests
  t_i: the average learning time of LM i
  v_ij: the learning effect that may be expected through one unit(time) learning of LM i
  T : The upper limit of sum of learning time
- Variable
  x_i: the variable that states LMi *should be learned x_i times*
- Formulation

$$\text{Maximize} \quad \sum_i \sum_j (1 - p_j) r_j v_{ij} x_i \qquad (1)$$

$$\text{Subject to} \quad \sum_i t_i x_i \leq T, \quad \forall i \qquad (2)$$

$$x_i \in \{0, 1\}, \quad \forall i \qquad (3)$$

The objective function p_j of equation (1) is the correct answer rate of the first diagnostic test and (1 - p_j) means the incorrect answer rate of the test. As the objective function is to be maximized, the LMs in the LEs that the incorrect answer rates were higher are preferentially selected. r_j is the appearance rates of the questions about LEj on the past tests, and as the appearance rate increases, so does the importance of the questions in the LE. v_ij shows the learning effect that may be expected through one unit (time) learning of LMi.

The variable x_i in the objective function is a selected decision variable. If x_i = 1, the LMi is selected, and the value of coefficient v_ij (1-p_j) r_j is added to the objective function (1). Otherwise, if x_i = 0, the LMi is not selected, and no values are added to the objective function (1). Hence, x_i with larger coefficients v_ij (1-p_j) r_j are chosen to maximize the objective function (1) as long as equation (2) is satisfied.

Equation (2), the first constraint condition, is the condition of simply not exceeding the upper limit of the total learning time. Equation (3) (binary constraint), the second constraint condition, is based on the premise that the same LM cannot be repeatedly learned. In the case that the LMs can be used repeatedly, integer constraints will be used, and the result that LM i should be learned xi times is obtained.

2.3. Numerical experiments

Here, we introduce a numerical example in which a formulation of equations (1), (2) and (3) is implemented using Excel Solver® that is a free add-in of Microsoft Excel®. Although it has limitations, Solver enables us to compute the optimization problems. The visual format of Solver is also convenient for introducing our numerical example.

There are 7 kinds of LEs. The orange cells in Figure 1 show the numbers of correct answers of the questions in the first diagnostic test of student A. From the numbers of correct answers, p_j and 1-p_j are calculated. In order to simplify this example, it is assumed that all the 7 kinds of LEs have a uniform appearance rate r_j of the questions.

Figure 1. the result of 2.3. Numerical experiments with MS Excel Solver

■Learning Materials Selection Problem

◆ Student A's ability (the results of a diagnostic test)

	LE A	LE B	LE C	LE D	LE E	LE F	LE G
no. of questions	30	30	30	30	30	30	30
no. of correct answers	6	3	3	9	24	24	21
p_j =	0.2	0.1	0.1	0.3	0.8	0.8	0.7
$(1-p_j)$ =	80%	90%	90%	70%	20%	20%	30%

value of the objective function (Max.)
Obj. = 42.9143

◆ the importance of each element (appearance rate of the element)

number of LEs = 7

r_j = 0.1429 0.1429 0.1429 0.1429 0.1429 0.1429 0.1429

upper limit of learning time (equation (2))

15 ≤ 15

($\Sigma t_i x_i \leq T$)

◆ LMs v_{ij} =   weak stress · plosives · linking · missing h · th sound · contracted · number of words

	no. of words		LE A	LE B	LE C	LE D	LE E	LE F	LE G	$\Sigma_i (1-p_j) r_j v_{ij}$	x_i	learning time
LM 001	30	no. of LEs	5	7	6	3	4	1	1	3.19	0	1
LM 002	26	no. of LEs	5	6	7	4	2	2	1	2.80	0	1
LM 003	34	no. of LEs	7	8	9	5	3	2	2	3.71	0	1
LM 004	30	no. of LEs	5	7	4	3	8	3	2	2.69	1	1
LM 005	31	no. of LEs	5	7	9	2	4	4	3	3.19	0	1
LM 006	32	no. of LEs	2	7	7	6	3	7	3	3.04	1	1
LM 007	31	no. of LEs	2	2	8	7	6	6	4	2.73	1	1
LM 008	31	no. of LEs	3	2	5	9	3	9	4	2.66	1	1
LM 009	45	no. of LEs	9	10	4	10	8	4	5	4.39	1	1
LM 010	30	no. of LEs	7	4	9	0	2	8	5	2.97	1	1
LM 011	7	no. of LEs	0	0	0	2	3	2	6	0.60	0	1
LM 012	29	no. of LEs	6	4	7	3	8	1	6	2.91	1	1
LM 013	35	no. of LEs	4	3	6	6	8	8	3	2.80	1	1
LM 014	32	no. of LEs	8	6	3	2	6	7	7	2.94	1	1
LM 015	30	no. of LEs	2	2	5	8	6	7	7	2.60	1	1
LM 016	31	no. of LEs	4	3	2	6	7	9	8	2.50	1	1
LM 017	31	no. of LEs	4	3	6	7	5	6	8	2.97	1	1
LM 018	29	no. of LEs	2	1	4	5	8	9	8	2.20	1	1
LM 019	30	no. of LEs	3	2	5	6	9	5	8	2.59	1	1
LM 020	34	no. of LEs	2	4	5	7	7	9	9	2.93	1	1

For each LM, the learning effect v_{ij} of each LE is defined. For example, the LM 001 has a learning effect of 9 for LE A, and has a learning effect of only 1 for LE F. Similarly, the LM 006 has a learning effect of only 2 for LE A, and has a learning effect of 7 for LE F. There are a total of 20 LMs in this numerical experiment, but we only select 15 LMs by means of optimization technique.

Setting Solver appropriately and executing the optimization, x_j changes to either 0 or 1 as shown the yellow cells in Fig 1. From this computation, Student A is advised to study LMs whose value of x_j equals to 1. According to the characteristics of Student A, it is considered that the LMs whose value of x_j is 0 have a lower priority than the LMs whose value of x_j is 1.

3.   Next Target

In this study, we proposed a mathematical approach that allows for the selection of learning materials that will have the largest effect on improving the weakness of the learner in order to maximize the learning effect within a limited learning time. However, we have not succeeded in implementing the model into the e-learning programs we have developed so far. In our future research, we would like to improve the accuracy of the model and realize the practical use of our e-learning programs.

4.   Acknowledgements

5.   References

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