Dynamic Question Paper Template Generation using Bi-proportional Scaling Method

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Abstract—**A Question Paper Template defines the scope of question paper with respect to syllabus contents and cognitive skills to be tested. Reforms in the educational system emphasize more on continuous assessment. Continuous assessment needs to test progress of study of various topics of a subject under various cognitive skills at different stages of learning. In order to assist instructors in continuous assessment process and ensure overall quality of the assessment, there is a need to generate Question Paper Templates dynamically and use these templates in framing examination question papers. This paper focuses on the application of Bi-proportional matrix scaling technique for generation of dynamic question paper templates. The results presented in the case study are promising to continue further research.**

Keywords-Educational Taxonomy; Question Paper Template; Bi-proportional Matrix Scaling; Seed Cells

I. INTRODUCTION

Examinations for every subject of a course are getting conducted either in external-mode or in internal-mode. End semester/External examinations cover all topics of a subject as well as all cognitive levels defined in taxonomy of educational objectives[1][2][3]. On the other hand, in-semester/internal examinations cover few topics of a subject and also few levels defined in an educational taxonomy. University specified Question Paper Format (QPF) acts as a standard in framing external and internal examination question papers. QPF specifies proper allotment of weights for all topics of a subject and the paper setter specifies allotment of weights for different cognitive levels to ensure the quality of an examination question paper. Using the QPF and the paper setter specified weights for different cognitive levels, a Question Paper Template (QPT) is formulated. QPTs having its scope spread across the entire contents of a subject as well as the cognitive domain of a taxonomy are found suitable in framing external examination question papers. However for framing internal examination question papers having its scope limited to few topics and few levels, these QPTs are not suitable. In [4], we designed dynamic templates by using evolutionary programming approach. Even though it generated population of QPTs, significant run time delay was observed during the population generation. In order to overcome this limitation, we propose a matrix balancing technique that automatically scales and balances all entries of the QPT. The bi-proportional matrix balancing technique performs iterative scaling and proportional fitting of the QPT to satisfy the instructor input number of topics, instructor input number of levels and instructor input marks requirement of each examination. This paper is organized as follows - Section 2 presents the research background & related work, the problem formulation is explained in Section 3, the bi-proportional matrix scaling procedure details for QPT generation is presented in Section 4, experimental case study is discussed in Section 5 and Section 6 concludes the paper.

II. RESEARCH BACKGROUND & RELATED WORK

The mathematical foundation and wide spread application of matrix scaling problem has attracted researchers from multiple disciplines to use it in various applications. Estimating the entries of a large matrix to satisfy a set of prior consistency requirements is a problem that frequently occurs in economics, transportation, statistics, regional science, operation research and other areas [5][6][7]. There are several scaling problems, each with different consistency requirements and therefore the definition of a scaled matrix is problem dependent [8][9]. To solve a problem using matrix scaling procedure, we need to identify the marginal tables and the seed cells. The procedure alternates between fitting the rows and fitting the columns of the seed cells to the identified marginal table entries. Result of the fitting process is a scaled matrix with corresponding set of estimated cell probabilities or cell means [10]. An L_1-error function is normally incorporated in matrix scaling problems for measuring the distance between current row and column sums and target row and column marginal entries. The procedure converges to bi-proportional fit if and only if the L_1-error tends to zero. In case of non-convergence, a separate procedure to handle error points (+e and –e) needs to be considered [11][12]. The seed cell entries can be of continuous variant or of discrete variant types [13]. In the continuous variant, nonnegative real numbers are permitted where as in the discrete variant, nonnegative integers are considered. Matrix scaling procedure with

978-0-7695-5141-8/13 $31.00 © 2013 IEEE
DOI 10.1109/T4E.2013.28

discrete variant is found appropriate for QPT scaling. The procedure alternates between fitting the topics and also fitting the cognitive levels and converges with a bi-proportionally scaled and balanced QPT. Cognitive processing levels of a QPT are decided on the basis of the taxonomy that is selected for each examination. The scaled QPT so generated is then used for framing a question paper by performing an intelligent selection of questions.

III. PROBLEM FORMULATION

In this section, we have highlighted the terminology used followed by the problem statement.

A. *Terminology Used*

TABLE I. TERMINOLOGY USED

Term	Meaning
Subject (S)	Paper offered in different semesters of a course.
M	Number of topics of subject syllabus file
N	Number of levels in the educational taxonomy.
Topic (T_I)	T_I specifies I^{th} topic of the subject syllabus
Educational Taxonomy Level (L_I)	L_I specifies I^{th} level of the educational taxonomy.
Topic Weight (TW_I)	TW_I is the weight assigned to the I^{th} topic.
Level Weight (LW_J)	LW_J is the weight assigned to the J^{th} level.
Topic-Level-Weight (W_{IJ})	Weight assigned to the I^{th} topic of J^{h} level.
Question Paper Template (QPT) of maximum marks TM	QPT is an M×N matrix with rows representing Topics T_I (I= 1 to M), columns representing Educational Taxonomy Levels L_J (J= 1 to N), cells representing I^{th} topic of J^{h} level W_{IJ} such that $\sum_{I=1}^{M} TW_I = \sum_{J=1}^{N} LW_J = TM$
Instructor	A person who taught the subject and carries out continuous assessment.
m, n, tm	m, n, tm are the instructor input number of topics, number of levels and total marks respectively for generating a scaled/dynamic QPT.
Scaled Topic-Level-Weight (w_{ij})	Scaled weight assigned to the i^{th} topic of j^{t} level.
Scaled Topic Weight (tw_i)	tw_i is the scaled weight assigned to the i^{th} topic.
Scaled Level Weight (lw_j)	lw_j is the scaled weight assigned to the j^{th} level.
Scaled QPT (qpt) of maximum marks tm	An m×n matrix generated from QPT by scaling its rows with respect to m topics and scaling its columns with respect to n levels such that $\sum_{i=1}^{m} tw_i = \sum_{j=1}^{n} lw_j = tm$, $tw_i = \sum_{j=1}^{n} w_{ij}$ and $lw_j = \sum_{i=1}^{m} w_{ij}$.

B. *Problem Statement*

Given a QPT for subject S of maximum marks TM as shown in Table II represented as a M×N matrix where M is the number of topics such that T={T_1, T_2,...,T_M}, N is the number of levels such that L={L_1,L_2,…,L_N} and each cell W_{IJ} representing the weight assigned to the I^{h} topic for the J^{th} taxonomy level, the problem is to dynamically generate *qpt* for the instructor input number of topics *m*, instructor input number of levels *n* and instructor input total marks *tm*.

TABLE II. QUESTION PAPER TEMPLATE (QPT)

Levels → / ↓ Topics	L_1	L_2	L_2	...	L_N	Cumulative Topic Weight
T_1	W_{11}	W_{12}	W_{13}	…	W_{1N}	TW_1
T_2	W_{21}	W_{22}	W_{23}	…	W_{2N}	TW_2
…	…	…	…	…	…	…
T_M	W_{M1}	W_{M2}	W_{M3}	…	W_{MN}	TW_M
Cumulative Level Weight	LW_1	LW_2	LW_3	…	LW_N	**TM**

IV. BI-PROPORTIONAL MATRIX SCALING FOR DYNAMIC QPT GENERATION

The main modules for scaled/dynamic QPT generation using bi-proportional matrix scaling procedure are shown in Fig.1.

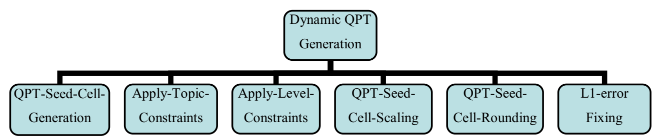

Figure1. Dynamic QPT Generation

Algorithm for Dynamic QPT Generation

Input: *QPT,*
instructor specified topics t=<t_1, t_2,...,t_m>,
instructor specified levels l= <l_1,l_2,…,l_n>,
instructor specified total marks tm
Output: *qpt (Scaled QPT)*
Begin
//QPT-Seed-Cell-Generation
For each t_i in t (i=1 to m)
For each l_j in l (j=1 to n)
$w_{ij} \leftarrow W_{IJ}$ // W_{IJ} is the weight for the I^{th} topic and J^{th} level of QPT for the corresponding instructor specified topic i and level j.
End For
End For
// Apply-Topic-Constraints
//Extract topic-weights corresponding to m topics
For i=1 to m
$tw_i \leftarrow \sum_{j=1}^{n} (w_{ij})$
End For
//Normalize the topic-weights with respect *to tm total marks*
For i=1 to m
$tw_i \leftarrow (tw_i / \sum_{i=1}^{m} tw_i) \times tm$
End For
// Apply-Level-Constraints
//Extract level-weights corresponding to n levels
For j=1 to n
$lw_j \leftarrow \sum_{i=1}^{m} (w_{ij})$
End For
//Normalize the level-weights with respect to tm total marks
For j=1 to n
$lw_j \leftarrow (lw_j / \sum_{j=1}^{n} lw_j) \times tm$
End For
//QPT-Seed-Cells-Scaling
flag_sum_tw=false
flag_sum_lw=false
While (flag_sum_tw = false || flag_sum_lw =false))
//check Seed-Cell meeting imposed topic constraints
For i= 1 to m
sum_tw $\leftarrow \sum_{j=1}^{n} w_{ij}$
If $tw_i \neq$ sum_tw ***then***

```
            Exit for
        Else if i=m then
            flag_sum_tw=true
        End If
        End For
    //check Seed-Cell meeting imposed level constraints
        For j= 1 to n
            sum_lw ← ∑ wij
            If lwj ≠ sum_lw then
                Exit for
            Else if j=n then
                flag_sum_lw=true
            End If
        End For
    // Scale seed-row and scale seed-column to fit them to scaled-topic-weights
                and scaled-level-weights
        If (flag_sum_tw = false || flag_sum_lw =false)
        // Seed-row-scaling
        For i= 1 to m
            For j= 1 to n
                wij ← (wij / ∑ wij )× twi
            End For
        End For
    // Seed-column-scaling
        For i= 1 to m
            For j= 1 to n
                wij ← (wij / ∑ wij )× lwj
            End For
        End For
    End If
End While
 Call QPT-Seed-Cell-Rounding
Call L1-error-Fixing
End
```

V. EXPERIMENTAL STUDY

Experimental study was carried out by considering Bloom's educational taxonomy with the following data-

1) S= Software Engineering (SE), a subject offered at the third year of the three year bachelor's degree course of computer science (B.Sc Computer Science) at Goa University; M=8; N=6; m= 6; n=4.

2) T= {fact finding, system analysis, system design, implementation, unit testing, system testing, maintenance, documentation}; t= {fact finding, system design, implementation, unit testing, maintenance, documentation}.

3) L={knowledge(kn),understanding(un),application(ap),analysis(an),synthesis(sy)evaluation(ev)};l={understanding, analysis, synthesis, evaluation}.

4) QPT= SEQPT, an end semester QPT of SE for maximum marks, TM= 100 is shown in Table III; tm =60.

TABLE III. SE QUESTION PAPER TEMPLATE (SEQPT)

Topic/Level	kn	un	ap	an	sy	ev	**Cumulative Topic Weight**
Fact Finding	1	4	1	1	6	2	15
System Analysis	1	6	2	2	2	2	15
System Design	1	2	2	1	2	2	10
Implementation	1	1	1	4	2	6	15
Unit Testing	1	1	2	2	2	2	10
System Testing	1	1	2	2	2	2	10
Maintenance	1	2	6	2	2	2	15
Documentation	4	1	1	1	1	2	10
Cumulative Level Weight	11	18	17	15	19	20	100

Sequence of steps carried out for Scaled/Dynamic SEQPT Generation is as below –

1) SEQPT-Seed-Cell-Generation: SEQPT seed cells are formulated by extracting SEQPT topic-level-weights corresponding to six selected topics and four selected levels. SE-Seed-Cells formulated are represented in Table IV below.

TABLE IV. SE- SEED- CELLS

4	1	6	2
2	1	2	2
1	4	2	6
1	2	2	2
2	2	2	2
1	1	1	2

2) Apply-Topic-Constraints: SEQPT scaled-topic-weights are generated by normalizing the topic weights of topics such as fact finding, system design, implementation, unit testing, maintenance and documentation with respect to 60 marks. SE-scaled-topic-weights say SE_tw generated are shown in Table V.

TABLE V. SE-SCALED-TOPIC-WEIGHTS

Topic	**SE-tw**
Fact Finding	15
System Design	7
Implementation	16
Unit Testing	8
Maintenance	8
Documentation	6
Total Marks	**60**

3) Apply-Level-Constraints: SEQPT scaled-level-weights are generated by normalizing the level weights of levels such as understanding, analysis, synthesis and evaluation with respect to 60 marks. SE-scaled-level-weights say SE-lw generated are represented in Table VI below.

TABLEVI. SE-SCALED-LEVEL-WEIGHTS

Level	**un**	**an**	**sy**	**ev**	**Total Marks**
SE-lw	13	12	17	18	**60**

4) SEQPT-Seed-Cell-Scaling: SEQPTs iterative alternate scaling starts by merging the SE-Seed-Cells with SE-tw and SE-lw. Initial stage of SE-Seed-Cell scaling is shown in Table VII below.

TABLEVII. INITIAL STAGE OF SEQPT- SEED- CELLS-SCALING

Start	13	12	17	18
15	4	1	6	2
7	2	1	2	2
16	1	4	2	6
8	1	2	2	2
8	2	2	2	2
6	1	1	1	2

SEQPTs iterative scaling continues until the scaled SEQPT say SE-qpt fulfills SE-tw and SE--lw. Iterative stages of SE-Seed-cells scaling and its termination at the fourth iteration is represented in Table VIII.

5) QPT-Seed-Cell-Rounding: Table IX represents the scaled and rounded integer values of SE-Seed-Cells at the end of fourth iteration.

6) L_1-error-Fixing: The near optimal SE-Seed-Cells of Table IX gets proportionately adjusted with +1 and –1 L_1-error. The SE-Seed-Cells generated after fixing L_1-error is shown in Table X. The resulting optimal SE-qpt is shown Table XI.

TABLE VIII. ITERATIVE STAGES OF SE- SEED -CELLS- SCALING

Iteration 1

Row Adjustment

	12.19	12.56	16.87	18.38
15	4.62	1.15	6.92	2.31
7	2.00	1.00	2.00	2.00
16	1.23	4.92	2.46	7.38
8	1.14	2.29	2.29	2.29
8	2.00	2.00	2.00	2.00
6	1.20	1.20	1.20	2.40

Column Adjustment

	13	12	17	18
15.26	4.92	1.10	6.98	2.26
7.06	2.13	0.96	2.02	1.96
15.73	1.31	4.70	2.48	7.23
7.94	1.22	2.18	2.30	2.24
8.02	2.13	1.91	2.02	1.96
5.99	1.28	1.15	1.21	2.35

Iteration 2

Row Adjustment

	12.93	12.07	16.92	18.09
15	4.84	1.08	6.86	2.22
7	2.11	0.95	2.00	1.94
16	1.34	4.78	2.52	7.36
8	1.23	2.20	2.32	2.25
8	2.13	1.91	2.01	1.95
6	1.28	1.15	1.21	2.36

Column Adjustment

	13	12	17	18
15.04	4.87	1.08	6.89	2.21
7.01	2.13	0.94	2.01	1.93
15.96	1.34	4.76	2.54	7.32
7.99	1.23	2.19	2.33	2.24
8.00	2.14	1.90	2.02	1.95
6.00	1.29	1.14	1.22	2.34

Iteration 3

Row Adjustment

	12.99	12.01	16.99	18.01
15	4.85	1.07	6.87	2.20
7	2.12	0.94	2.00	1.93
16	1.35	4.77	2.54	7.34
8	1.24	2.19	2.33	2.25
8	2.14	1.90	2.02	1.94
6	1.29	1.14	1.22	2.35

Column Adjustment

	13	12	17	18
15.01	4.86	1.07	6.87	2.20
7.00	2.13	0.94	2.01	1.93
15.99	1.35	4.77	2.54	7.34
8.00	1.24	2.19	2.33	2.24
8.00	2.14	1.89	2.02	1.94
6.00	1.29	1.14	1.22	2.34

Iteration 4

Row Adjustment

	13.00	12.00	17.00	18.00
15	4.85	1.07	6.87	2.20
7	2.13	0.94	2.01	1.93
16	1.35	4.77	2.54	7.34
8	1.24	2.19	2.33	2.24
8	2.14	1.89	2.02	1.94
6	1.29	1.14	1.22	2.35

Column Adjustment

	13	12	17	18
15	4.85	1.07	6.87	2.20
7	2.13	0.94	2.01	1.93
16	1.35	4.77	2.55	7.34
8	1.24	2.19	2.33	2.24
8	2.14	1.89	2.02	1.94
6	1.29	1.14	1.22	2.34

TABLE IX. SCALED AND ROUNDED SE-SEED- CELLS

	13	12	17	18
15	5	1	7	2
7	2	1	2	2
16	1	5	3	7
8	1	2	2	2
8	2	2	2	2
6	1	1	1	2

TABLE X. SE-SEED- CELLS AFTER L_1-ERROR FIXING

	13	12	17	18
15	5	1	7	2
7	2	1	2	2
16	1	5	3	7
8	2	2	2	2
8	2	2	2	2
6	1	1	1	3

TABLE XI. SCALED / DYNAMIC SE-QPT

Topic/Level	un	an	sy	ev	Cumulative Topic weights
Fact Finding	5	1	7	2	15
System Design	2	1	2	2	7
Implementation	1	5	3	7	16
Unit Testing	2	2	2	2	8
Maintenance	2	2	2	2	8
Documentation	1	1	1	3	6
Cumulative Level weight	13	12	17	18	**60**

VI. CONCLUSION

Continuous assessment requires the generation of dynamic question papers for different examinations. Automatically generating dynamic QPT satisfying the instructors input number of topics and instructors input number of taxonomy levels is very important in situations where novice instructors wish to formulate question papers for different variant iteratively scales the QPT, assigns integer valued marks under different levels of a topic and generates a bi-proportionally scaled and balanced QPT. The dynamic QPT so generated can drastically reduce the time and effort of the user while ensuring question paper quality also.

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