

# A Web Application for the Knowledge Space Theory Analysis: KST Web

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**Abstract**—Traditionally people who are not familiar with programming tools such as Visual Basic and R programming languages have some difficulty in generating chi-square values, the knowledge structure graphs, and even the critical learning paths. This paper describes release 1.0 of a web application for the analysis of knowledge space theory, a free publicly available web application that offers both the chi-square computation and graphs for knowledge structures and critical learning paths. We present a freely available web application that helps those people who need to utilize the knowledge space theory. This paper contains a detailed description of the web application, including its various features, such as an environment development, knowledge states, and a computation of the chi-square and the critical learning paths. The explanation used here introduces the web application to the non-programmers enabling them to generate knowledge spaces.

**Keywords**—Knowledge Space Theory; Knowledge Structure; Critical Learning Paths

## I. INTRODUCTION

Over the last few years, the use of web application has considerably increased in our daily life and the influence of the web application method on various fields, such as engineering, math, physics and computing, has grown up with the technology.

Traditionally, in the field of mathematical psychology, many efforts to form a knowledge space that describes knowledge states of a human learner have been manually performed not just by applying time consuming but also by generating unexpected errors.

In order to solve the problems (time consuming and error occurring) some studies have done properly using R programming language [1], a statistical computing language. An R package for data analysis methods in knowledge space theory (DAKS) was introduced to perform basic operations in knowledge space theory [2]. The DAKS uses the package sets [3], relations [4], Rgraphviz [5] from Bioconductor<sup>1</sup>, generating knowledge structures. However, the DAKS only works on R environment and does not work on the web. Recently, a knowledge space theory package [6] has been added to the R environment and has helped researchers generate knowledge structures in particular domain. But, the

package depends on the R environment as well. Meanwhile, rApache project [7] was presented in DSC 2005 Seattle<sup>2</sup>. The rApache supports a web application development with R and Apache web server.

In this paper, we introduce a freely available web application for the knowledge space theory analysis (KST Web.)<sup>3</sup> that not only computes critical learning paths which describes the most probable sequences of learning steps but also generates the knowledge structure on the web.

The contributions of this paper follow:

- KST Web. is a freely available web application so that researchers who want to use for their researches can access to the application anytime on the internet.
- Chi-squared test is automatically performed on the web instead of using Visual Basic programming [8] on the local machine.
- Knowledge structures and critical learning paths are generated on the web.

The rest of the paper is organized follows: Section 2 briefly describes knowledge space theory as a part of related work, section 3 presents our web application, section 4 compares our web application with others' attributes and shows experiment results, and finally section 5 concludes.

## II. KNOWLEDGE SPACE THEORY

In the area of mathematical psychology, a knowledge space [9] is a theoretical knowledge structure that describes a human learner's possible knowledge states in a specific domain. Knowledge space theory is based on the knowledge state of the learner and has been used in various tests and tutoring scenarios [10][11]. The basic idea of knowledge space theory is that a knowledge state of a human learner is viewed as set of problems that the learner is able to solve. For example, a knowledge state of a student can be in the form of a question to which the student has to answer. Let's assumed that there are items,  $\{a, b\}$  in a knowledge state, corresponding to the student who can solve the items ( $a$  is a question about multiplication,  $b$  is a question about both addition and multiplication). If the student is able to solve the

<sup>1</sup> <http://www.bioconductor.org>

<sup>2</sup> <http://www.r-project.org/conferences/DSC-2005/>

<sup>3</sup> <http://tobouli.cs.gsu.edu/~slee172/KSTWeb/>

item *b* then we may be able to infer that the student also can solve *a*. This scenario is quite simple because we only used two items in the knowledge space.

The responses of human learners were analyzed to determine the knowledge structure and critical learning path. A response state is derived from the set of questions answered correctly by a learner and the response state is used to identify a subset of response states in the analysis of the knowledge space structure. The response states are called knowledge states. Probability values computed by its population rates are considered as a key for critical learning paths and finally the most apposite learning paths becomes the critical learning paths.

### III. THE KST WEB APPLICATION

In this section, we present our web application. The web application environment is introduced in section A and section B explains about how to generate assumed knowledge space. Section C describes the computation of chi-squared value and section D shows the generation of knowledge structures and critical learning paths.

#### A. System Environment

In this section, we will introduce the environment of the web application. The web application has been developed on Linux System (Fedora). All codes used for the knowledge spaces are run on the system. Table 1 describes the software versions used in the web application. We used the web programming language Java-script for computing the chi-square and used the statistical programming language R for generating the knowledge spaces. The web development tool rApache is used for communicating the R with the Apache web server. Therefore, the Java-script will display the chi-square results and the rApache will display the knowledge spaces.

- Operating System: Linux (Fedora release 14)
- Web Programming Language: HTML, Javascript
- Programming Language: R version 2.13.1
- Web development tool: rApache version 1.2.3

#### B. Generating the assumed knowledge structure

This section explains about how to generate the assumed knowledge structure on the web application. In general, knowledge space responses were scored in a binary fashion converting response structures to knowledge structures. The assumed knowledge structure is generated from the knowledge response structures. Our web application provides two ways of generating the assumed knowledge structure that has a 0 value for the population in each response state.

Figure 1 shows an example of the knowledge response states (Top). The first column represents the knowledge state for each question and the second column represents the number of responses. The initial assumed knowledge structure is generated from the knowledge response states (Left on the bottom). The number of knowledge states is same with the number of knowledge states in the knowledge response states. The converted assumed knowledge structure is generated from the knowledge response states (Right on the bottom), however

the number of knowledge states is increased because the additional knowledge states are inserted into the states when the conversion of the knowledge structure performed. But, in the initial assumed knowledge structure, the additional knowledge states are not generated. The chi-square will be computed based on the difference between the predicted and the real populations in the assumed knowledge structure.

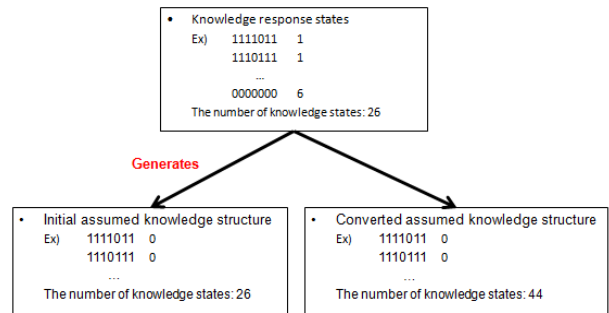


Fig. 1 Assumed knowledge structures

#### C. Chi-Squire computation

Traditionally, many calculations are performed using a Visual Basic computer program, Potter's program [7]. The program performs well for the knowledge space theory analysis, calculating the predicted knowledge state population in the assumed state and generating the chi-square value from the real and predicted population. Our application computes the chi-square, using the algorithm of the Potter's program.

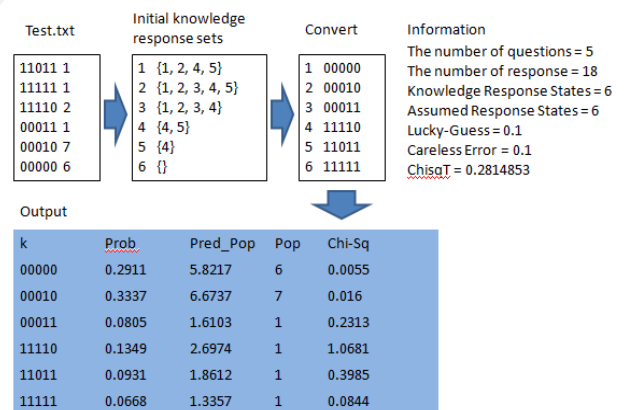


Fig. 2 Dataflow for the Chi-Squire

Figure 2 shows the dataflow for a sample file "Text.txt" generating the chi-square value using our web application. First, the sample file is converted into the initial knowledge response sets. Then, the converted knowledge response sets are used to generate the output with the information of the question number, response number, response numbers, luck-guess probability, and careless error probability. For our experiment in the section 6, we set the probabilities of the luck-guess and careless error to 0.1. The output shows various elements: the first column represents the questions, the second column represents the probability of the population in the response state, the third column represents the predicted population and the fourth column represents the real population, and the last column represents the chi-square that

is calculated from the real and predicted population. Our web application displays all the elements above.

**D. Critical learning paths and knowledge structure**

The critical learning paths are the characteristic hierarchies of the concepts, describing the most probable sequences of learning steps. The pathways contain knowledge states with the highest populations. The pseudo-code of the critical learning paths is provided in Figure 3.

The first inputs to the critical learning paths include a population of knowledge states P and a question of knowledge states Q, and the output of the procedure is the critical learning path CLP. The main procedure performs three steps: Step 1 finds the first list-arrays with the highest populations in the first row which is the fewest questions among all list arrays. Step2 finds the list-arrays with the highest population in the next row among the first list arrays. Step3 repeats the Step 1 and Step 2. Our web application provides the knowledge structure tree that shows critical learning paths presenting the progression of the responses.

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Procedure KS(P, Q)
Inputs:
P /* population of knowledge states
Q /* question of knowledge states
Output:
CLP /* critical learning path
Main Procedure:
1. Select KS with the highest P and fewest Q as the head of CLP.
2. Identify the highest P superset of the selected head as the second set.
3. Repeat the steps
    
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Fig. 3 Algorithm for the Critical Learning Path

Figure 4 presents the knowledge structure and the critical learning paths generated by using the data from Figure 2. The final results show that the critical learning pathway is {}-{4}-{5}-{1, 2}-{3}. Thus, we can determine that taking the 4<sup>th</sup> question first -> taking the 5<sup>th</sup> question -> taking the 1<sup>st</sup> and 2<sup>nd</sup> questions -> taking 3<sup>rd</sup> question is the critical learning path.

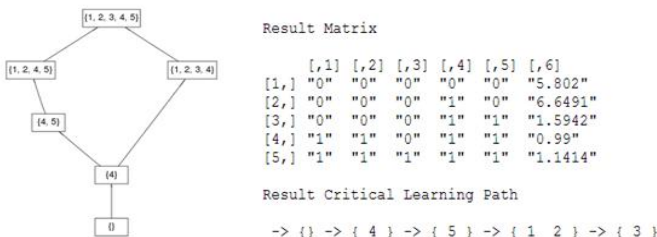


Fig. 4 Knowledge structure (Left) and critical learning paths (right)

**IV. EXPERIMENTS**

In this section, we compare our web application with other approaches. Moreover, in order to verify the robustness of our application, we compared the results of our application with the baseline results: the Chi-square total using Porter’s

Visual Program and the Critical learning path using manually computed.

Table 1 shows the comparison of knowledge space theory analysis (KST analysis). The methodology of KST web which is based on the web is different from DAKS, KST, and Potter because they are all local based approaches. KST web and Potter only generate the chi-squared value for the KST analysis. Furthermore, KST web only computes the critical learning path and displays the path on the web.

Table 1 Comparison of knowledge space theory analysis

	KST Web.	DAKS[2]	KST[6]	Potter[8]
Methodology	Web based	Local based	Local based	Local based
Packages	kst packages, Rgraphviz	sets, relations, Rgraphviz	many kst packages	No
Chi-Squared value	Yes	No	No	Yes
Learning paths	Critical Learning Path	Hasse diagram	Lpath()/lpath_is_gradation()	No pathway optimization
Web support	Yes	No	No	No
Implement Language	Javascript and R	R	R	Visual Basic

We describe the experimental results for chi-squared values and critical learning paths. Two experts performed the critical learning path computation manually using the real dataset which comes from the assessments given within the six weeks of the class. The experiments are performed with different two tests: Test1 and Test2. Two tests consist of the comparison group and the experimental group respectively. In the two groups, 7 questions are used for the Test 1 and 6 questions are used for Test 2. Total 44 populations are used for the comparison group and total 39 populations are used for the experimental group. Table 2 and Table 3 show the experiment results for the comparison group and the experimental group. The chi-square value is almost same with the baseline and the critical learning path is same with the manually computed values.

Table 2 First test experiments

	Test 1		Test 2	
	Baseline	Web Application	Baseline	Web Application
Chi-square total	2.044773799	2.044774	7.845916438	7.845916
Critical learning paths	6-1-7-2-3-5	6-1-7-2-3-5	2-1-6-5-3,4	2-1-6-5-3,4

Table 3 Second test experiments

	Test 1		Test 2	
	Baseline	Web Application	Baseline	Web Application
Chi-square total	11.50172093	11.50172	4.067165353	4.067165
Critical learning paths	6-3-1-7-2-4-5	6-3-1-7-2-4-5	1,2-5-3-4-6	1,2-5-3-4-6

## V. CONCLUSION

We presented a web application that computes the chi-square and represents the knowledge spaces automatically. The web application also provides the graphical knowledge structures. The experimental results showed that the performance of our application is almost the same as the Potter's Visual Basic program, a well-known knowledge space analysis tool and is also similar to the manually computed critical learning paths. Recently, some researchers tried to use the knowledge space theory in the problem solving environment [12] and in the formal concept analysis [13]. We expect that our web application would be very helpful for students or researchers who are not familiar with basic programming tools but would like to generate the knowledge spaces.

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