Three-dimensional modeling of knowledge space and application in the SWEBOK

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Abstract. The proposition of SWEBOK (Software Engineering Body of Knowledge) provides criterion for the organization and effective management of software engineering knowledge. How to use SWEBOK guide the learning of software engineering related professions has become a real question. This essay constructs an evaluation model of software engineering knowledge in the space of Three-dimensional knowledge and describes the specific decision-making method that using the evaluation model to guide the software engineering related professions learn SWEBOK on the basis of analyzing those professions.

Introduction

The research of knowledge has always been the basic and heart question of library science and information science, its main fields relates to knowledge organization, knowledge management, knowledge evaluation[1].Software engineering is one of the most knowledge intensive works in human history [2].All the knowledge that made from the activities that relate with software engineering can be called software engineering domain knowledge. Recently, with the rapid development of the Internet industry, software outsourcing and IT industry, software engineer becomes one of the most attractive professions in home and abroad. The famous American employment network CareerCast did a survey in 2012, and in the ten best careers that selected according to the comprehensive income, working environment, and development prospect etc. Software engineer ranks first. In the recent investigation of the college graduates' career in China, software engineer's income has also been leading the way. Therefore, in the study of software engineering domain knowledge, the following three researches need in-depth discussions. (1)How effectively organize and manage the software engineering knowledge[3]. (2)How to quantitative evaluate the software engineering knowledge. (3) How to effectively make software engineering knowledge services related software engineering career better.

To realize effective organization and management of the software engineering domain knowledge, one of the core points is to have a backbone classification system for relevant knowledge[4].SWEBOK was developed by ACM and IEEE CS joint working group in 1993 and after 20 years of constantly improve, check and modification, the third edition was published in 2014.The establishment of SWEBOK provides the management and organizational basis for software engineering domain knowledge[5] . Scientists study found that constructing multi-dimensional space can greatly improve the possibility in the specification of objects' actual state and their correlation[6], can establish a quantitative evaluation of software engineering knowledge from multi-dimension on the basis of knowledge space. Due to the software engineering related career more and more appreciated, it becomes increasingly significant to provide decision support for the software engineering related professional on the basis of the quantitative evaluation of knowledge.

Based on the conceptual model of knowledge space, this thesis sets up the knowledge evaluation model of software engineering, combining Bloom's taxonomy level and both the difficulty level and

time taken for knowledge learning. Besides, this thesis also makes instance analyses of this model by using decision-making algorithm, which provides learners of related occupations in software engineering field with decision-making methods of software engineering discipline knowledge.

Theoretical basics of Knowledge Space Modeling

Knowledge Space and Evaluation Model of Related Knowledge. Different researchers have different definitions on the concept of knowledge space mode. In the year of 1985, Doignon and Falmagne suggested the knowledge space theory is based on understanding science which describes a given domain knowledge of the structure of the method[7]. In 1999, Zhijin Wang et al., put forward the word: knowledge space in article" knowledge space: the concept of knowledge organization foundation" which probes the multi-dimensional model of knowledge structure[8]. On the basis of the concept of knowledge space.

The main purpose of this paper is to study knowledge which is limited on the software engineering professional knowledge, and given priority to text software engineering knowledge.

SWEBOK. Software Engineering Body of Knowledge(SWEBOK) is published by the IEEEcomputer society which is direct at the standard of division on software engineering knowledge[5]. In 1993, IEEE computer society and Association for Computer Machinery jointly promoted the corresponding standards and specifications about professional software engineering, SWEBOK version 3 was push put in 2014. At the latest version of the software engineering body of knowledge which includes 4 basic knowledge area, 11 software engineering practice knowledge area. See Figure 1.

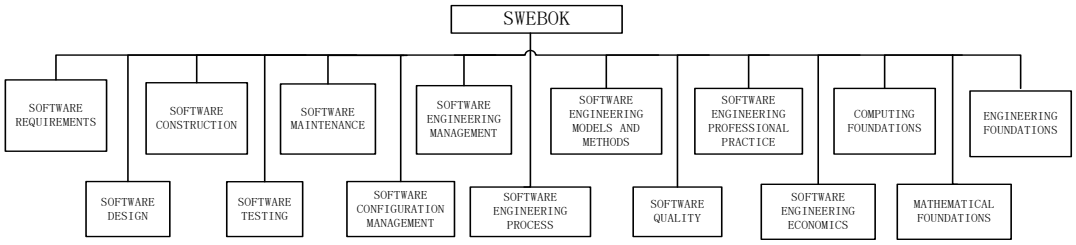
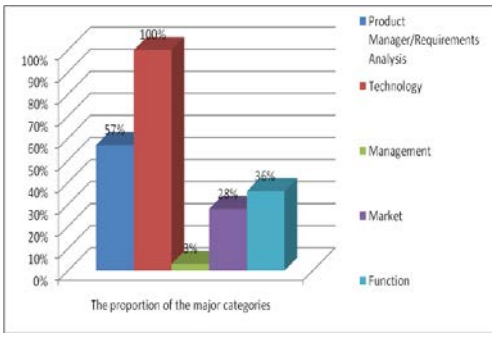


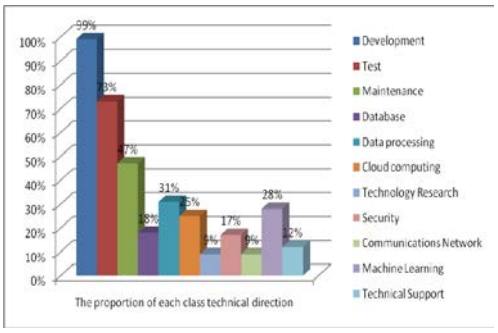
Fig. 1 SWEBOK V3

The divided of SWEBOK for software engineering knowledge has been recognition in industry, and is a broad consensus on the knowledge, has gradually become the standard of software engineering knowledge classification.This article is proceed materialization about 102 large knowledge point inside 15 knowledge area in SWEBOK V3[9]. Also, after materialization of knowledge conduct as the main content of the questionnaire.

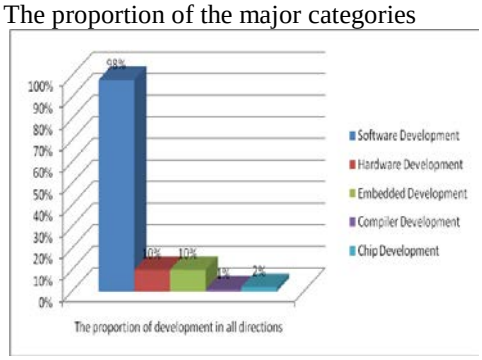
Related software engineering job analysis. From 2009 to 2015, Chinese software market rose from 15.45 billion Yuan to 188.99 billion Yuan in 2015. Based on stipulation on "classifications ceremony of the People's Republic of China" that promulgated on July 29, 2015[10], with a connection to the computer software employee is mainly engaged in the study of application software design, development, testing, integration, maintenance and management of engineering and technical personnel. The authors investigated the Internet related to software engineering, software outsourcing and IT industry, find out 50 companies in top 100 Chinese Internet companies in 2015 issued by the ministry of industry and information technology, and also precede position investigation through 50 companies between software outsourcing companies and IT organizations which ranking the front of Internet. It investigate the job mainly divide into requirement analysis/product manager, technology, management, market, function five categories. Proportion to development and testing direction is relatively high in the technical categories. The direction of software development has absolute advantagecompared with other development direction in development direction. In software development groups, it has higher proportion on position of development of mobile terminal and Java development direction. Results as follow Figure 2.



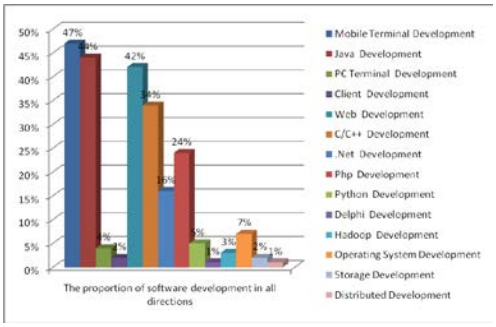
The proportion of the major categories



The proportion of each class technical direction



The proportion of development in all directions



The proportion of software development in all directions

Fig. 2 Related Occupations proportion of Software Engineering

Through the above data analysis, it can discover that in related jobs on software engineering, the proportion of software development and software testing jobs is comparatively stand out. In the software development, it has a closely relationship on research on Android's and the direction of the Java language.Therefore, the direction of the research object of this paper is mainly on the personnel of Java language and software testing jobs.

Bloom's Taxonomy Level. Bloom's taxonomy level is a well-known educational and cognitive classification method. It is divided into six areas, Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation. In SWEBOK V2[11], the Bloom's Taxonomy level is used to indicate the degree of knowledge need to know. This article cognitives Bloom taxonomy level as a dimension of knowledge related to software engineering to master degree studies to reflect the importance of this knowledge points.

The three-dimensional model of knowledge space and Decision algorithms

Three-dimensional model of knowledge space. This article builds the three-dimensional model of knowledge space according to Prof. Zhijing Wang's concept with Bloom's taxonomy level as one dimension, the degree of difficulty and the time of learning as the other two dimensions. The model is as following:

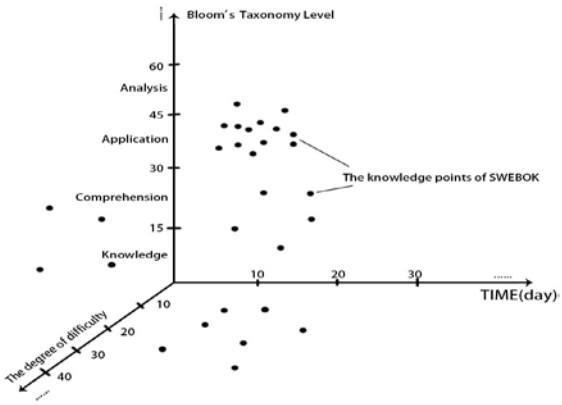


Fig. 3 Three-dimensional modeling of knowledge space

Based on the figure above, we can evaluate 102 knowledge points in software engineering system according to Bloom's taxonomy level(the master degree), the degree of difficulty and the time of learning.

Decision Methods. Analytic Hierarchy Process was presented by Saaty, an American operational research expert in 1970s[11].This method divides the elements related to decisions into goal, criteria, alternatives layers, which is the basis of making qualitative and quantitative analysis decision methods. AHP depends more on subjective consciousness. This thesis obtains data by making questionnaire from the people who are learning or working in software engineering field and subjective consciousness play an important role when obtaining data, so this thesis uses AHP.The principles and steps are elaborated on as follows.

Step 1. Analysing the relationship among different elements and building Hierarchical structure model. These differentlayers can be divided into three clusters: The highest layer(Goal), an intermediate layer (Criteria), the bottom layer(Alternatives).

Step 2. Comparing significance between elements in same layer and the guideline in previous layer and construct the matrix to make comparison:Judgment Matrix. Judgment Matrix uses numerals 1-9 and theirreciprocalsas the scale to define importance extent, as follows Table 1.

Table 1 Judgment matrix defined scale

Relative importance	Definition	Explanation
1	Equally important	i equally important goal than j
3	Somewhat important	i a little more important than j
5	Very important	i important than j
7	Obviously important	i obviously more important than j
9	Absolutely important	i absolutely more important than j
2，4，6，8	Between two important degree	

Step 3. Single-layer sorting and consistency check.

(1) Calculate Consistency Index: CI, which can be calculated using equation(1):

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{1}$$

$\lambda_{\max}$ is the largest eigenvalue of judgment matrix, n is the order of square matrix.

(2) Find Consistency Indexvalues: RI, which can be found using table 2.

Table 2.Mean Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0	0.52	0.89	1.12	1.24	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58

(3) Calculate Consistency Ratio: CR, which can be calculated using equation(2):

$$CR = \frac{CI}{RI} \tag{2}$$

When CR<0.10, we can believe that the consistency of Judgment Matrix is acceptable. Otherwise, we should appropriately amend theJudgment Matrix.

Step 4: The total layer sorting and consistency check Making consistency check for the total layer sorting, and calculating the total synthesis system target weights of the elements in different layers and sorting the selected programs.

In this thesis, according to principles and steps of AHP, we first use Bloom’s taxonomy level, the degree of difficulty of knowledge and the time taken which taking to learn knowledge these three data to construct three-dimensionalJudgment Matrix. And then making a summary of knowledge point in different knowledge area in SWEBOK, and calculating the proportion of knowledge area and constructing the Judgment Matrix of every dimensions. Finally, calculating the right order in knowledge area by AHP.

Data acquisition and experimental verification

The design of the questionnaire. In this paper, we design a questionnaire consisting of 102 questions extracted from 15 knowledge areas and 102 1st class content items in SWEBOK V3. We index these knowledge key points according to Bloom's taxonomy level, the difficulty level and time consumption. Note that all these three dimensions are evaluated under a 90 points scale. Thus, a higher index score usually represents greater hardness of the knowledge level and time consumption needed to learn the corresponding point.

Selection on the survey objects. According to our preliminary survey on related works in Software Engineering field, we find that the Java development and sortware test works earn the highest rate in company's job hiring. In this degree, we select some Java development engineers and testers to finish our survey in order to obtain our dataset.

Data Pre-processing. In all, we survey 105 individuals consisting of 53 Java development engineers and 3 survey questionnaires are unqualified; 52 software test engineers and 2 questionnaires are abandoned. Thus, we have 100 qualified questionnaires in total. According to our elementary analysis, we find that both Java developers and testers hold the idea that three key knowledge aspects: software construction, software testing and computing foundation have the highest scores in Bloom Classification Theory, i.e., owns the highest importance weight. Hence, we employ data from these three fields to establish our calculation in decision algorithm.

Hierarchical structure model's building. According to the basic principle and steps of analytic hierarchy process (AHP), the first step is to build the hierarchys tructure model. The specific model is shown in figure 4.

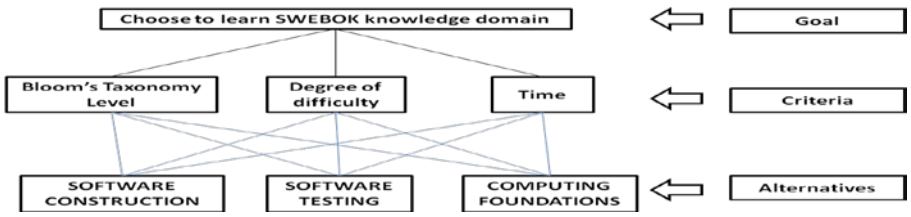


Fig. 4 Hierarchical structure model

Goal layer is the order we choose to learn the knowledge area, criteria layer is the three dimensions in the software engineering knowledge space, alternatives layer is the weight value of software construction, software testing, and computing foundations,according to the weights of order we can know the sequence learning of knowledge area.

The construction of judge-matrix. According to the statistic, we first use the data of Java development direction to estimate the construction of judge-matrix andjudge-matrixes are shown in table 3, table 4, table 5 and table 6. The percentage of analytic hierarchy process(AHP) is the integer or the integer's reciprocal, because the data we collect need to do summary first and then compute in proportion, so the data we get have decimal.

Table 3 Judgment Matrix on three dimensions(Java)

Knowledge Area	Bloom	Degree of difficulty	Time
Bloom	1	4.848	7.904
Degree of difficulty	0.206	1	3.2
Time	0.127	0.313	1

Table 4 Judgment Matrix on Bloom's Taxonomy Level(Java)

Bloom	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	0.769	0.829
Software Construction	1.300	1	1.077
Software Testing	1.206	0.928	1

Table 5 Judgment Matrix on the degree of difficulty(Java)

Degree of difficulty	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	0.967	0.947
Software Construction	1.034	1	1.022
Software Testing	1.056	1.022	1

Table 6 Judgment Matrix on Time(Java)

Time	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	0.967	1.093
Software Construction	1.034	1	1.131
Software Testing	0.915	0.884	1

Then, we use the software testing direction's data to estimate the construction of judge-matrix,the judge-matrix are shown in table 7, table 8, table9 and table 10.

Table 7 Judgment Matrix on three dimensions(Test)

Knowledge Area	Bloom	Degree of difficulty	Time
Bloom	1	4.651	7.624
Degree of difficulty	0.215	1	2.933
Time	0.131	0.341	1

Table 8 Judgment Matrix on Bloom's Taxonomy Level(Test)

Bloom	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	0.875	0.753
Software Construction	1.143	1	0.864
Software Testing	1.328	1.162	1

Table 9 Judgment Matrix on the degree of difficulty(Test)

Degree of difficulty	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	1.254	1.079
Software Construction	0.797	1	1.163
Software Testing	0.927	0.860	1

Table 10 Judgment Matrix on Time(Test)

Time	Computing Foundations	Software Construction	Software Testing
Computing Foundations	1	0.949	1.132
Software Construction	1.054	1	1.193
Software Testing	0.883	0.838	1

The single order and the total order andconsistency check of hierarchy. In the hierarchy's single order, the consistency ratio matrix of JAVA development direction is {0.0438,0,0.0126,0}, and every count in the matrix is less than 0.1, through the consistency check; The The consistency ratio matrix of software testing direction is {0.0325,0,0.0086,0.000}, every count in the matrix is less than 0.1, through the consistency check.

In the hierarchy's total order, the consistency ratio of JAVA development direction is 0.0024, less than 0.1, through the consistency check; The consistency ratio of software testing is 0.0186, less than 0.1, through the consistency check;

Desiccation resolution. By calculation, the sequence to lean three knowledges areas from the JAVA development direction and software test direction are shown in table 11, table 12.

Table 11 Learn the order of knowledge area(Java)

Knowledge Area	Sorted weight	Learning order
Software Construction	0.3630	1
Software	0.3408	2

Table 12 Learn the order of knowledge area(Test)

Knowledge Area	Sorted weight	Learning order
Software Testing	0.3620	1
Software	0.3306	2

Testing Computing Foundations	0.2962	3	Construction Computing Foundations	0.3074	3

Through the statistic we can know that the sequence to lean three knowledge areas for the JAVA development direction is software construction, software testing ,computing foundations and the sequence to lean three knowledge areas for the software testing direction is software testing, software construction, computing foundations. Through the further analysis of the specific content in SWEBOK's three knowledge areas and the deep analysis of the software engineer professions, the research result truly shows the learning sequence of Java development and software testing. Meanwhile, it also proves the analytic hierarchy process (AHP) can provide good management support for those who learn SWEBOK knowledge area.

Summary

This essay proposed the evaluate model of three-dimension knowledge of software engineer according to the theory of multidimensional model in knowledge space, it combines with the relevant professional software engineering analysis, acquired data from questionnaire on SWEBOK base of software construction, software testing, computing foundations through software development enginerrs and software test engineer the two position.This essay has just make the experimental analysis about the knowledge area of SWEBOK, has not do analysis in the specific knowledge points, and it is the working emphasis of my next work.

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