A Wiki-based Collective Intelligence Approach to Formulate a Body of Knowledge (BOK) for a New Discipline

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ABSTRACT
This paper describes a wiki-based collective intelligence approach to provide a system environment that enables users to formulate a body of knowledge (BOK) for a new discipline, such as social informatics. When the targeted discipline is mature, for example, computer science, its BOK can be straightforwardly formulated by a task force using a top-down approach. However, in the case of a new discipline, it is presumed that nobody has a comprehensive understanding of it; therefore, the formulation of BOK in such a field can be carried out using a bottom-up approach. In other words, a collective intelligence approach supporting such work seems promising. This paper proposes the BOK+ which is a novel BOK formulation principle for new disciplines. To realize this principle, the BOK Constructor is designed and prototyped where Semantic MediaWiki (SMW) is used to provide its basic functions. The BOK Constructor consists of a BOK Editor, SMW, Uploader, and BOK Miner. Most of the fundamental functions of the BOK Constructor, with the exception of the BOK Miner, were implemented. We validated that the BOK Constructor serves its intended purpose.

Categories and Subject Descriptors
H.5.3 [**INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)**]: Group and Organization Interfaces – *Web-based interaction, Collaborative computing, Theory and models.*

General Terms
Management, Documentation, Design, Human Factors.

Keywords
Wiki, Semantic MediaWiki (SMW), collective intelligence, body of knowledge (BOK), discipline, BOK Constructor.

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1. INTRODUCTION

1.1 Motivation and Research Purposes
With the development of the Internet, the Web can be accessed in every corner of the world, and thus, we may call modern society the "Web society." However, there exist various congestion problems, which may be termed the "social informatics phenomena." Since traditional sciences do not seem to work toward resolving such problems, expectations are placed on new disciplines such as "social informatics" (hereafter, SI). However, a comprehensive understanding of this new discipline is not yet available. For example, if we consider SI, although there are articles (e.g., [1], [2]) defining SI, they may not be adequate because they give no consideration to SI's body of knowledge (BOK).

In general, a discipline is defined on the basis of its BOK. Several BOK formulation works have been carried out until now. For example, the Joint Task Force of the IEEE Computer Society (IEEE-CS) and Association for Computing Machinery (ACM) formulated a BOK for computer science called the Computer Science Body of Knowledge (CSBOK) [3]. There are other BOK formulation projects such as the Project Management Body of Knowledge (PMBOK) [4], Software Engineering Body of Knowledge (SWEBOK) [5], and Information System Body of Knowledge (ISBOK) [6]. From among these, the CSBOK is interesting in that it is defined as a three-tiered conceptual "tree."

Now, although the social informatics body of knowledge (SIBOK, hereafter) has yet to be formulated, our current aim is not to build the SIBOK, because the methodology to formulate a BOK for a "new" discipline is yet to be discovered. Rather, our attempt is to develop a system environment wherein any people in education and research in a new discipline can collaborate to formulate its BOK. Following the authors' initial report [7], this paper presents a BOK design principle for new disciplines named the BOK+; it also provides the prototyping of a system termed the "BOK Constructor," which provides graphical user interfaces for

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users to upload materials, edit descriptions, and edit a BOK tree as a collective intelligence in a bottom-up manner. Semantic MediaWiki (SMW, hereafter) [8] is used as the core of this system. material.

1.2 Significance of This Research

As stated in the previous section, we do not aim to formulate the SIBOK but to provide a wiki-based prototype to help people in education and research collaboratively formulate the BOK of a new discipline such as SI. In this section, we will highlight the significance of this research: if we could formulate the BOK of a new discipline, then what could be the expected academic effects if we considered the SIBOK construction as an example?

Imagine that an SIBOK is formulated under the collective intelligence approach. Then, because the SIBOK reflects a consensus among the professionals in this discipline, it is understood that it is regarded as the "reference" SIBOK in the following two senses:

(a) Relativization of disciplines

(b) Relativization of educational institutes

Figure 1 shows the relativization of type (a). It shows that if we could formulate the SIBOK, then we could relativize it, that is, visualize the relative position of the SIBOK, CSBOK, and the BOK of social sciences so that a deeper understanding of a targeted discipline can be achieved.

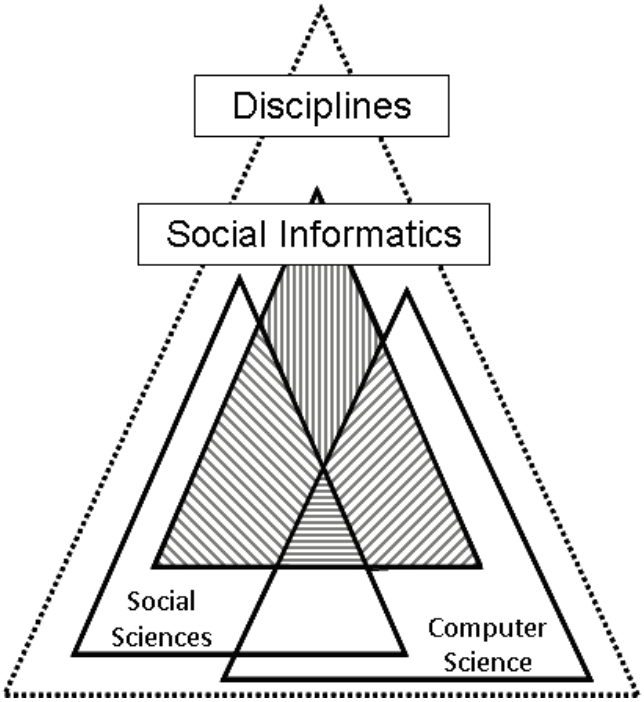

Figure 1. Relativization of disciplines.

Figure 2 shows the relativization of type (b). In this case, it is supposed that institute A formulated its own SIBOK-A, and institute B, its own SIBOK-B. By comparing themselves with each other, each institute could ascertain its position with respect to the other institute. Therefore, although the names of the schools are the same, for example, the "school of social informatics," they could identify differing views on the same discipline. Needless to say, such relativization could be useful in other disciplines besides SI.

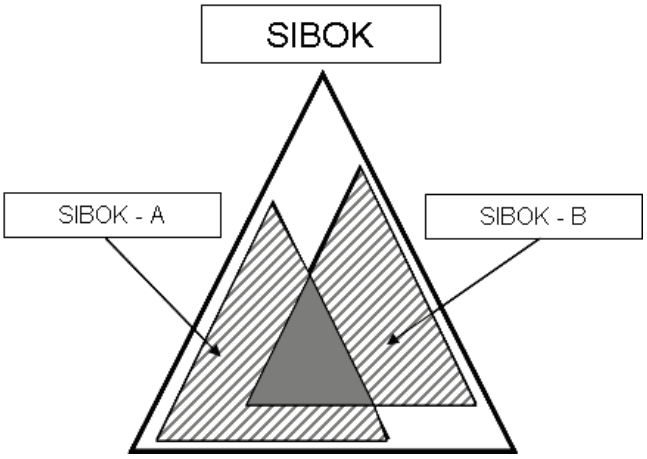

Figure 2. Relativization of educational institutes.

The remaining sections of this paper are as follows: related works are discussed in section 2; the design philosophy of the BOK formulation for new disciplines is explained in section 3; BOK Constructor prototyping is illustrated in section 4; and the conclusions are drawn in section 5.

2. Related Works

Two related works are cited in this section. First, the CSBOK (Computer Science BOK) is discussed as a typical example of a BOK of a traditional discipline. Second, Wikipedia is referred to and compared with the BOK Constructor.

2.1 CSBOK

CSBOK seems to be a typical example of a well-defined BOK that is open to the public. It was formulated by the Joint Task Force on Computing Curricula, which comprises members from the IEEE-CS and the ACM. CSBOK is interesting in that it presents the body of knowledge in the form of a three-tiered "tree." That is, the task force insists that "computing" consists of five disciplines, namely, computer science, computer engineering, software engineering, information technology, and information systems. The CSBOK insists that "computer science" is divided into 14 areas, which constitute the first-level nodes of the tree. Then, each area is divided into several sub-areas called "units," which constitute the second-level nodes. Again, each unit is divided into several sub-areas called "topics," which constitute the third-level nodes. Figure 3 shows a part of the tree structure of the CSBOK.

It should be noted that the CSBOK was formulated in a top-down manner; this is because the task force had a comprehensive understanding of computer science at the time when the CSBOK was being formulated.

In contrast, it would not have been possible to obtain a comprehensive understanding of a new discipline if attempts were made to formulate its BOK. Therefore, the formulation work will be carried out in a bottom-up manner. This is discussed in section 3.1.

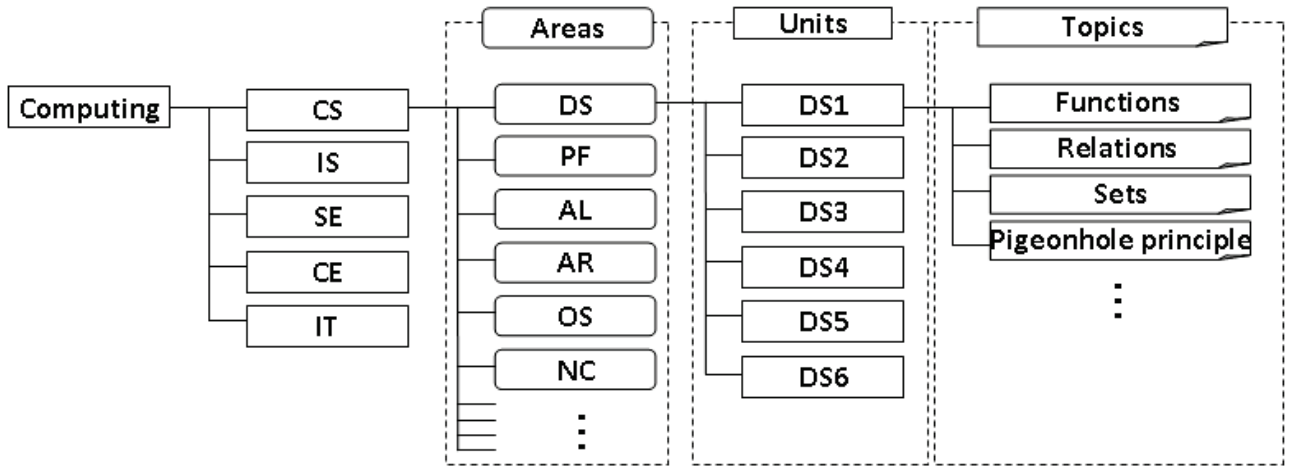

Figure 3. Tree structure of CSBOK.

2.2 Wikipedia

Wikipedia is considered one of the most successful wiki applications. Its English version currently contains 3,293,493 articles. In addition to English, there are versions in 271 different languages [9]. A set of Wikipedia pages constitutes a semantic network in which "reference links" are defined among pages. Since a more detailed introduction to Wikipedia is easily available, we will not delve further on it in this paper.

As will be discussed in the following sections, a BOK that is constructed by the BOK Constructor formulates a "tree," which is considered to be a restricted version of a semantic network. This difference between Wikipedia and the BOK Constructor can be attributed to the purpose they serve: the former aims to construct a free online encyclopedia that anyone can edit, whereas the latter intends to provide a wiki-based environment for people in a specific discipline, to formulate a body of knowledge for that discipline, which is represented by a "conceptual tree."

The similarities and dissimilarities between Wikipedia and the BOK Constructor are summarized as follows. Both take a collective intelligence approach on the basis of wiki clones. More precisely, Wikipedia uses MediaWiki while the BOK Constructor uses SMW as its engine for knowledge management. One of the essential differences between Wikipedia and the BOK Constructor is the editing system, that is, the rules for creating and deleting wiki pages: in contrast to Wikipedia, the rules for editing the wiki pages of the BOK Constructor are a little restrictive; the editors are usually requested to upload materials first, create the descriptions, and then edit the BOK tree. A more detailed description will be given in the subsequent sections.

3. A Novel BOK Formulation Principle for New Disciplines

3.1 Necessity of Collective Intelligence Approach

In general, a BOK of a well-established discipline is formulated by a large-scale task force comprising the authorities in the discipline. A typical example is the CSBOK that was formulated by the Joint Task Force of the IEEE-CS and ACM. In such cases, BOKs are formulated in a "top-down" manner, in the sense that the task force has a global view of the BOK of the targeted discipline when it begins work. In other words, since the group has an in-depth knowledge of the discipline from the initial stage, it can perform a step-by-step breakdown of the knowledge at the top level of the targeted discipline into its sub-areas so that a BOK tree can be obtained.

In contrast, if a discipline is new, then the top-down approach would not work because nobody has a comprehensive understanding of the discipline. An example of such a discipline is SI. Therefore, it is presumed that the BOK in such a study field can be constructed in a "bottom-up" manner. Since the bottom-up approach means to create existence from nothing, collaboration is essentially necessary among people who want to build it up in the discipline. Note that "collaboration" implies a collective intelligence approach, as used in James Surowiecki's book, *The Wisdom of Crowds* [10]. Further, we understand that collective intelligence can be realized through the use of a "wiki clone," which provides a quick collaboration on the Web [11].

3.2 BOK+

In order to formulate a BOK in a bottom-up manner, we need "materials" from which we can extract knowledge about the targeted discipline. We paid special attention to the materials used, such as PowerPoint slides, documents, articles, and books that are used in education and research in the targeted discipline. By analyzing the materials, we presumed that a certain level of knowledge could be obtained and used to formulate a BOK.

BOK+ is the general name for the three types of resources that the BOK Constructor manages, and it is a term to refer to a novel BOK design principle for new disciplines as well. The resources are materials, descriptions, and the BOK tree, which are linked. Figure 4 gives an overview of BOK+. The set of all materials constitutes a class named "Material." By referring to the materials, people participating in the formulation of a targeted discipline's BOK, can select an academic topic to describe its content. This is done using a wiki page, and it is termed a "description." Descriptions can be linked together under semantic links. The set

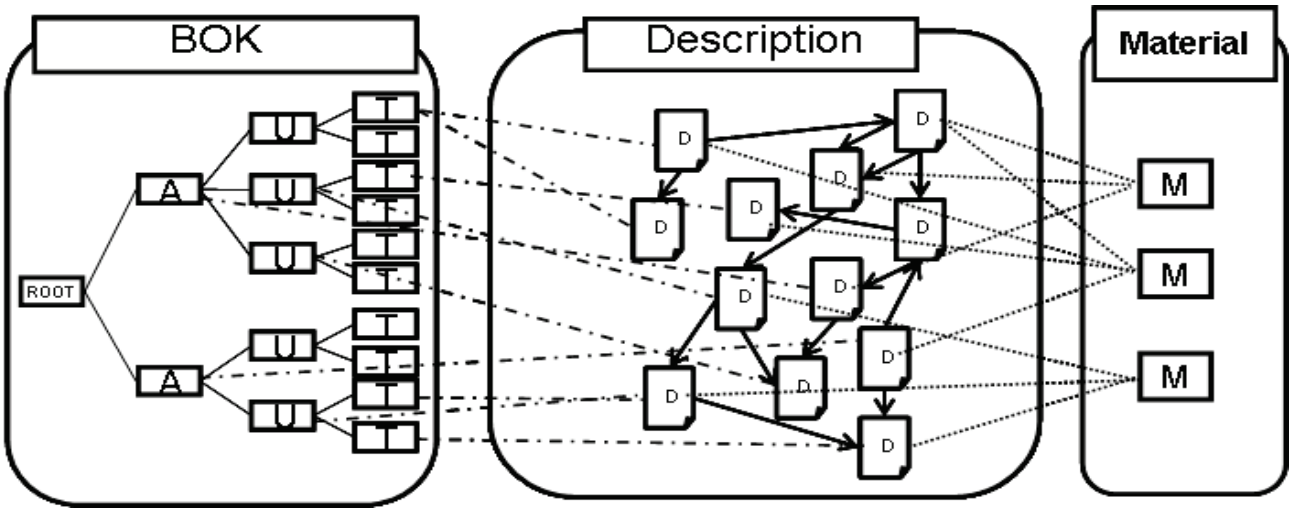

Figure 4. An overview of BOK+.

of all descriptions constitutes a class named "Description." BOK represents a BOK tree, and it is collaboratively formulated stepwise by the people. In order to assist in their formulation work, the BOK Constructor may seed with a kernel BOK that is constructed by analyzing the descriptions of the Description class. To formulate the seed, Wikipedia mining technology [12] could be helpful. Once the seed is made available, the people can begin collaboratively editing it in order to obtain the final form of the BOK.

3.3 BOK Constructor

The BOK Constructor was designed to assist people when they performed their collaborative work. It manages BOK+ resources and provides graphical user interfaces (GUI) to make their work easier. SMW is used to store the nodes of a BOK tree, descriptions, and wiki pages that refer to the actual data files storing the materials. Figure 5 gives an overview of the BOK Constructor. As it is shown, it consists of four modules: BOK Editor, SMW, Uploader, and BOK Miner.

The BOK Editor provides the editing functions for the BOK through a GUI and maintains the editing rules of the BOK, such as Wikipedia's three-revert rule. SMW is used to store wiki pages that describe materials, descriptions, and BOK tree. Note that we neither intend to modify MediaWiki nor implement a new extension of it; instead, we wish to use it for storage so that the BOK Editor is implemented as a "wrapper" of SMW. This is simply because we do not want to create a new wiki clone. The Uploader is introduced to upload the materials. When a user interacts with the BOK Editor to upload material, the BOK Editor asks the Uploader to store the material as a data file and also asks SMW to create a wiki page with a pointer to the data file. To help the BOK formulation people, the BOK Miner can display a BOK tree by mining all the wiki pages in the Description class by using a certain mining algorithm. We presume that the BOK Miner is

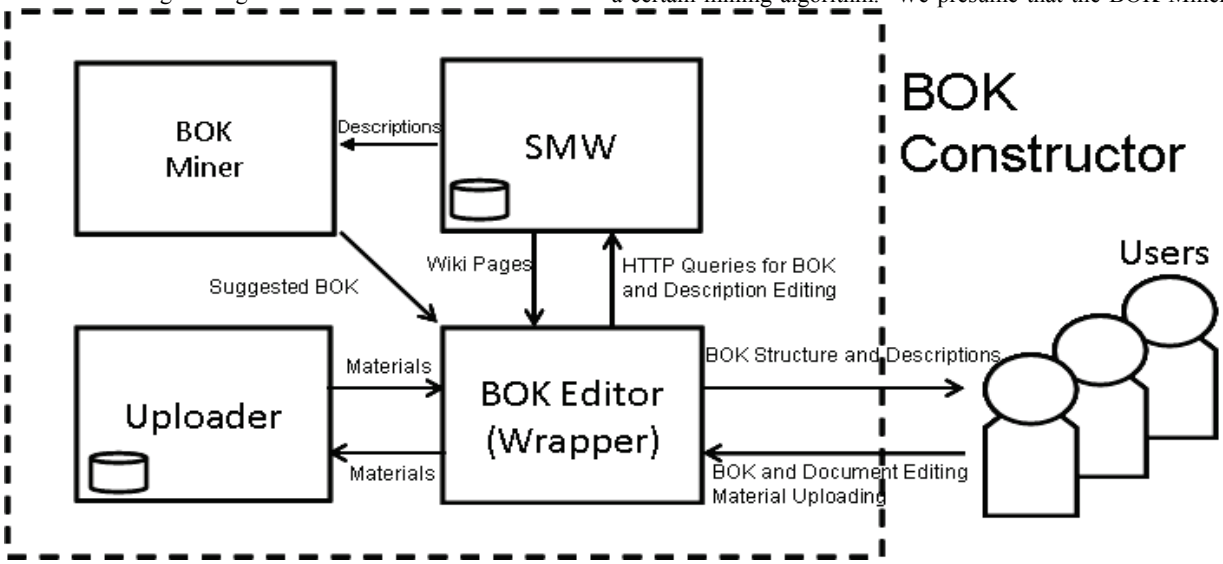

Figure 5. An overview of the BOK Constructor.

particularly helpful at the first stage of the BOK formulation process: it can show a speculative draft or a "seed" of the BOK from which the people can begin their work. However the BOK Miner development is left as a future work. More detailed explanation of the BOK Editor is given in the following sections.

3.4 BOK Editing Functions

As stated in the previous section, we presume that the "seed" is given to the BOK by the BOK Miner, and the editing work is started by the BOK formulation people. Since we presumed that the BOK is a tree structure and, similar to CSBOK, it could be a three-tiered tree, the following two types of tree operations are necessary to perform the BOK formulating work.

(a) BOK node creation, deletion, and move

(b) Providing semantic links among BOK nodes

By applying the type (a) operations, an initial BOK tree with arbitral depth will be normalized into a three-tiered tree, that is, a tree with the root node labeled with the name of the discipline, for example, SI. The first-level nodes represent the "areas" of the discipline; the second-level nodes represent the "units" of the discipline, which are the sub-areas of an area; and the third-level nodes represent the "topics" of the discipline, which are the sub-areas of a unit. We presume that the three-tiered representation of BOK is as reasonable as it is for CSBOK.

Type (b) operations are necessary particularly for the subsequent two purposes: (i) representing hypernyms or hyponyms, and (ii) representing synonyms or homonyms. A more detailed explanation is given in section 4.2.

4. BOK Constructor Prototyping

4.1 Details of BOK Constructor Implementation

The basic components of the BOK Constructor, with the exception of the BOK Miner, were implemented. Figure 6 presents the details of the implementation. Several Web development techniques and programming languages were used in the implementation: Ajax, PHP, Python, Ruby, and Ruby on Rails. Except for some optional settings, the BOK Constructor uses SMW as it is. As is already known, MediaWiki is implemented using PHP. MySQL is used to store wiki pages. To implement the BOK Editor functions, Ajax, PHP, Ruby, and Python are used. Ajax is used to implement the GUI; Python, to communicate with SMW; Ruby, to implement the BOK tree; and Ruby on Rails, to implement both the communication with the Uploader and the CGI function. The function to allow communication between the BOK Editor and SMW is implemented using MediaWikiAPI, a built-in function of MediaWiki, where the MWClient—written by using Python—is used as a library. Uploader is implemented by Ruby on Rails, and MySQL is used to store data files, that is, materials. The communication between the BOK Editor and Uploader is realized through the message communication function of Ruby on Rails because both modules run on the same server, while communication between the BOK Editor and SMW, which run on different servers, is realized through an HTTP protocol. In order to obtain articles written in the WikiML from SMW, the export function, which is a standard built-in function of MediaWiki, is used.

4.2 Management of BOK+

As described in Section 3.2, BOK+ is the general name for the three types of resources that the BOK Constructor manages: materials, descriptions, and BOK tree, which are linked together. Remember that these resources are necessary to realize a bottom-

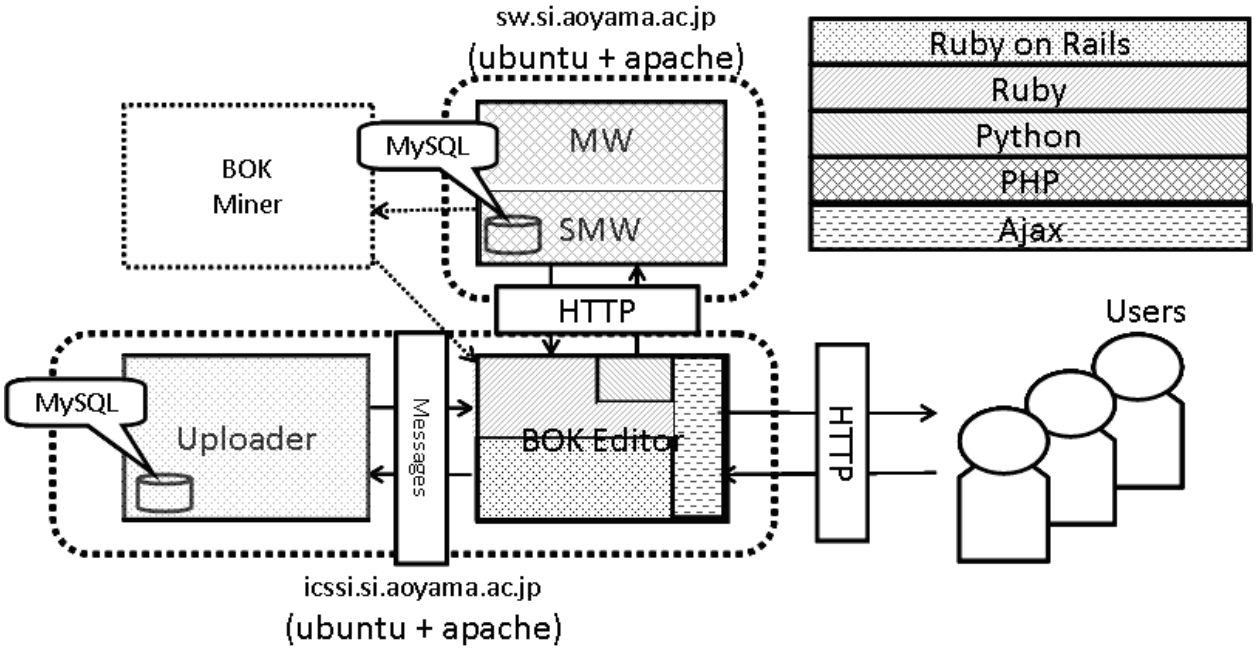

Figure 6. Details of BOK Constructor implementation.

up approach for the BOK formulation of a new discipline. To manage materials, descriptions, and BOK tree under SMW, classes termed Material, Description, and BOK, respectively, are introduced. Actually classes are namespaces of MediaWiki. This section shows how these classes are defined in the BOK Constructor.

4.2.1 Material Class

To manage uploaded material files that are stored using MySQL in the Uploader, the Material class is introduced in SMW. When a material is uploaded, a wiki page is created to refer to it. The Material class has the attributes that are shown in Table 1. The attribute "ID" is for identifying a material; "FilePath" is for pointing to the material file; "FileName" is the name of the material file; and "RefferedBy" is for pointing to a set of instances in the Description class, which refer to the material as reasoning.

Table 1. Attributes of the Material Class

Attribute	Data Type	Cardinality Constraint	Explanation
ID	Integer	1	Serial number
FilePath	Pointer to File	1	File address
FileName	String	1	File name when uploaded
ReferredBy	Pointer to Description	0..n	Link to descriptions
Outline	String	0..1	Bibliography information

4.2.2 Description Class

The people engaging the BOK formulation work create wiki pages that describe the topics of the targeted discipline with or without referring to a certain set of materials. Such wiki pages form class Description. The descriptions are very important in that a skeleton or a draft of the BOK can be created by mining the class. The Description class may constitute a semantic network under the reference links, as in Wikipedia. The reference links are defined in the body of the wiki pages. Table 2 presents the attributes of the Description class. The attribute "DescriptionName" describes the name of the description; attribute "ReferredBy" points to a set of BOK nodes, which refer to the description as reasoning; attribute "Refer" defines the reverse links of those defined by the attribute "RefferedBy" introduced in the Material class; and attribute "Body" stores text written in a natural language.

Table 2. Attributes of the Description Class

Attribute	Data Type	Cardinality Constraint	Explanation
Description Name	String	1	Own name
ReferredBy	Pointer to BOK	0..n	Link to BOK tree nodes
Refer	Pointer to Material	0..n	Link to materials
Body	String	0..1	Text written in a natural language

4.2.3 BOK Class

The purpose of the BOK class is to manage wiki pages that represent the nodes of a BOK tree. Table 3 presents the attributes of the BOK class. The attribute "NodeName" indicates the name of the BOK node. The attributes "Hypernym" and "Hyponym" represent hyponymys. The attributes "Synonym" and "Homonym" are introduced to refer to synonyms and homonyms respectively, if any exist. The attribute "Level" indicates the level of the node in the BOK tree (root is in level 0), and the attribute "Refer" is for pointing out members of the Description class referred by the BOK node, if any exist.

Table 3. Attributes of the BOK Class

Attribute	Data Type	Cardinality Constraint	Explanation
NodeName	String	1	Own name
Hypernym	Pointer to BOK	0..1	Link to a broader concept
Hyponym	Pointer to BOK	0..n	Link to narrower concepts
Level	String	1	Root or Area or Unit or Topic
Synonym	Pointer to BOK	0..n	Link to synonyms
Homonym	Pointer to BOK	0..n	Link to homonyms
Refer	Pointer to Description	1..n	Link to descriptions

As was illustrated above, BOK+ is regarded as a semantic network where the network elements are the wiki pages created in the classes of Material, Description, and BOK, and the semantic links are some of the attributes defined in the classes. This information is important when mining BOK+.

4.3 Details of the BOK Editor Implementation

In the current implementation, the BOK Editor provides three different types of BOK+ editing functions through the What You

See Is What You Get (WYSIWYG) user interfaces: (a) Main Editor View, (b) Description–Material Link Editor View, and (c) BOK Nodes Linking View. Details of the functions provided by these views are described below.

4.3.1 Main Editor View

Through this view, users can edit BOK+. Figure 7 is a snapshot of the Main Editor View. As shown in the figure, this view has four sub-windows. The leftmost sub-window shows the BOK tree under editing. The BOK is shown in a hierarchical manner as a directory-type tree so that users can edit BOK nodes as if they are managed by an outline processor. By left-clicking on a BOK node in this sub-window, the linked description title appears in the upper-middle sub-window and the linked description body appears in the lower right sub-window simultaneously, so that users can understand what the BOK node means. If there is a set of materials to be linked to that description, the file names of such materials appear in the upper-right sub-window. By right clicking on a BOK node in the leftmost sub-window, a pop-up menu is opened so that users can add a child to that node by clicking on the ADD button in the menu and moving the node to a child of a designated BOK node by clicking on the MOVE button in the menu. Users can add, edit, or delete a description by clicking on a button located at the bottom of the upper-middle sub-window. In addition, users can add, open, or delete a material by clicking on a button located at the bottom of the upper-right sub-window.

4.3.2 Description–Material Link Editor View

Through this view, users can define the links between the descriptions and the materials uploaded. Figure 8 shows a snapshot of the Description–Material Link Editor View. This view offers four sub-windows. The upper-left sub-window is used to list all the descriptions in the Description class. If a user clicks on an item that is displayed in that sub-window, its text is displayed in the lower-left sub-window and the user can confirm the content. The upper-right sub-window is used to list all materials in the Material class. An explanation of the material clicked on in that sub-window appears in the lower-right sub-window. However, the essential function of this view is to allow a user to define a set of reference links from a description to the set of materials that are referred to by this description. This is done by clicking a description item first and then clicking on a set of material items to be referred to by that description, before clicking on the Apply button. Although users can edit links between Description and Material using the Main Editor View, the editing capability is limited in that editing through the Description–Material Link Editor View can be done in a more comprehensive manner.

4.3.3 BOK Nodes Linking View

This view is purpose-oriented: to define synonyms, that is, different words with identical or very similar meanings, and to define homonyms, that is, words that sound or are spelled the same but have different meanings. Note that hypernyms and hyponyms are words that refer to a general category and a specific instance of that category, respectively, and these relationships are defined by the hierarchical structure of the BOK tree. Figure 9 is a snapshot of the BOK Nodes Linking View. There are three parallel sub-windows simultaneously depicting the BOK tree in the directory-type tree. In order to define the synonyms and homonyms of words, users can click to select a BOK node in the leftmost window and click to select a set of BOK nodes in the middle sub-window to define them as the words' synonyms, or click to select a set of BOK nodes in the rightmost sub-window to define them as the words' homonyms. We presumed that the synonym links and the homonym links become important when the targeted discipline of BOK formulation is "interdisciplinary."

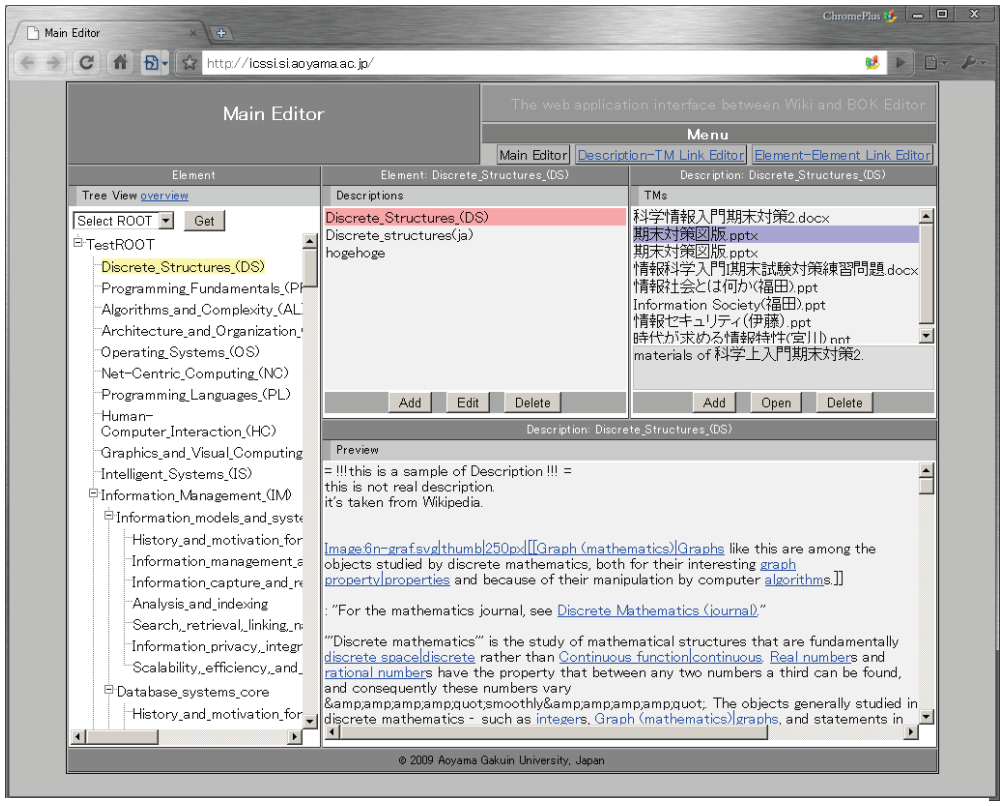

Figure 7. Snapshot of the Main Editor View.

4.4 Verification of BOK Constructor Implementation

Although the BOK Constructor is under development, we have tested the basic functions mentioned above using a part of the CSBOK and Library of Congress Classification (LCC) [13], which also constitutes a conceptual tree. CSBOK formulates a BOK of computer science, while Class H (social sciences) of LCC is presumed to constitute a conceptual tree of the social science BOK. More specifically, all the 14 area names—all the units and topics under the area termed "Information Management" (IM) of the CSBOK—were input through the BOK Editor. It was performed as expected. In the case of the LCC, all the subclasses of Class H and all the subclasses of "Industries.Land_use.Labor," "Finance," and "Social_pathology.Social_and_public_welfare.Criminology" were extracted and input through the BOK Editor. This was carried out without any problems, too. The CSBOK and LCC were selected for the test because we presumed that SI could be a newly created interdisciplinary field of study with computer science and social science as its fundamental disciplines. The total number of wiki pages created in SMW is 343, which includes 287 pages representing the BOK nodes in addition to the fixed pages for class description, garbage box, and a root node description. The materials we used were teaching materials, that is, the PowerPoint slides used in our institute, the School of Social Informatics, Aoyama Gakuin University. We have confirmed that all the operations described in the previous sections worked as expected.

5. Conclusions and Future Work

Formulating the BOK of a new discipline, in particular, becomes very difficult because of its novelty. In such a case, the traditional top-down approach to formulate a BOK does not work, and it seems that the bottom-up approach is necessary to resolve the problem. In this paper, we have proposed the BOK+ which is a novel BOK formulation principle for new disciplines, and designed and prototyped a BOK Constructor that assists people in education and research in the discipline to identify the knowledge structure of the targeted discipline in a collaborative manner. In order to formulate a BOK in a bottom-up manner, the BOK Constructor manages BOK+, which consists of a set of three kinds of wiki pages: those belonging to the classes of Material, Description, and BOK. The BOK Constructor consists of a BOK Editor, Semantic MediaWiki, Uploader, and BOK Miner. Most of the fundamental functions of the BOK Constructor, with the exception of the BOK Miner, were implemented. We validated that the BOK Constructor serves its intended purpose.

Future works include two main issues. The first thing is the design and implementation of the BOK Miner. We presume that the Wikipedia mining technology may help in this regard. The second thing is to conduct accurate and in-depth preliminary experiments involving people from SI field of study even under the current implementation of the BOK Constructor to formulate the SIBOK. If the SIBOK is successfully formulated, then we can design the ideal curriculum for social informatics. In addition, the relativization of disciplines or of institutes is an interesting by-product. The BOK Constructor may help not only in formulating a BOK of a new discipline but also in other areas where the body of knowledge mining is required.

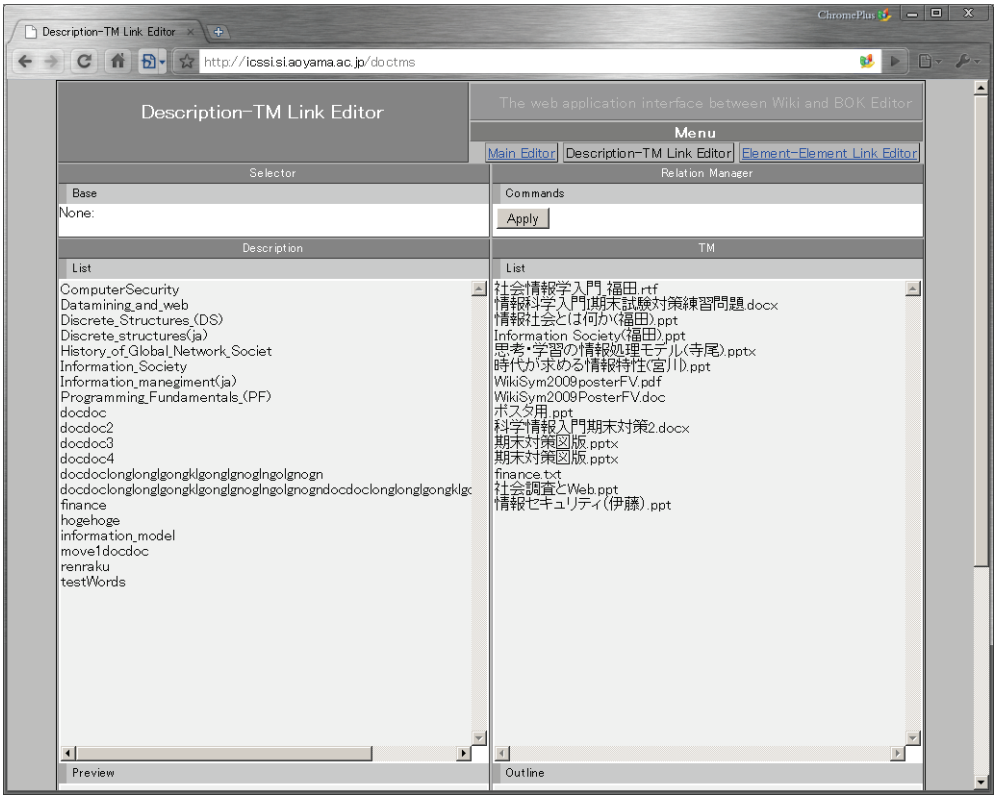

Figure 8. Snapshot of the Description–Material Link Editor View.

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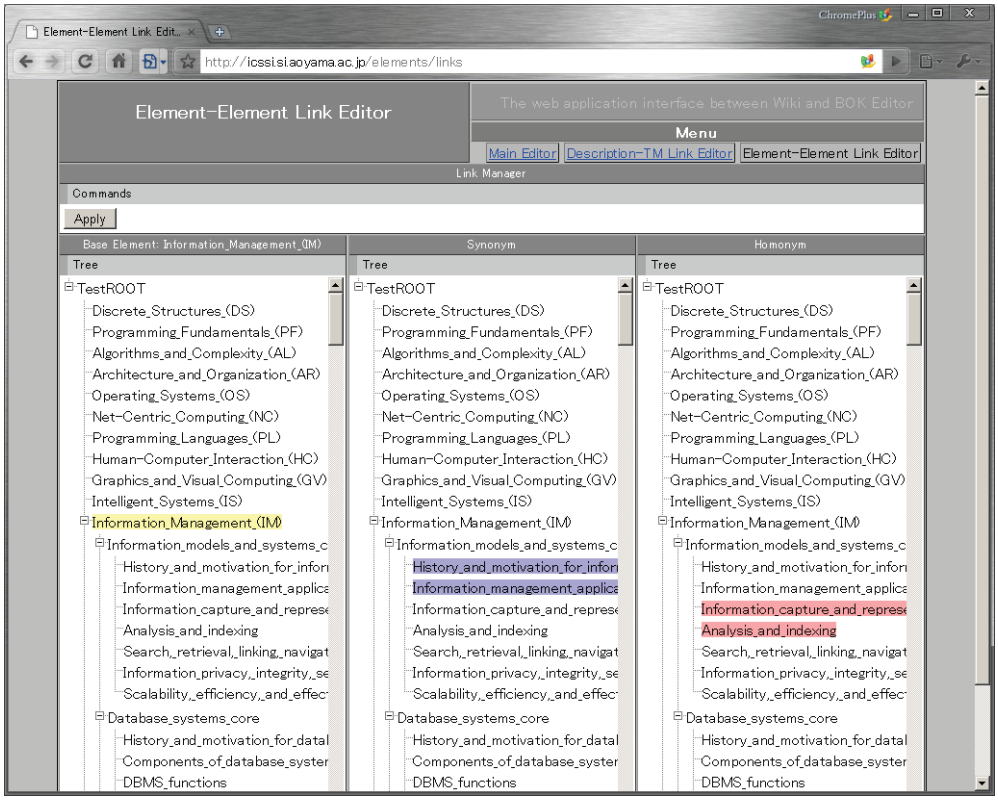

Figure 9. Snapshot of BOK Nodes Linking View.