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Development of the Visualizing System of Knowledge Structure Based on STEM e-Learning Website

Akira Nakamura*, Tomoshige Kudo, Keita Nishioka
Academic Foundations Programs,
Kanazawa Institute of Technology Ohgigaoka,
Nonoichi, Japan
*Corresponding Author: n.akira@neptune.kanazawa-it.ac.jp

ABSTRACT

Many people have been gradually building the knowledge of STEM (Science, Technology, Engineering and Mathematics) for a long time and new knowledge is created based on previous knowledge. Therefore, all knowledge is related to each other and structured. Currently, knowledge structure of STEM is huge and complicated. We consider that visualization of knowledge structure is very useful for learning STEM. By acquiring knowledge structure students can understand STEM more deeply and learning speed is accelerated. From this background, we developed the system visualizing the knowledge structure of STEM. We realize visualization of knowledge structure by using a network graph of hyperlink structure of STEM e-learning website which we have been developing. In order to analyze the hyperlink structure we developed crawler software and computed the data for graph drawing. The website contains about one thousand units of knowledge. In the graph drawing a node indicates a unit of knowledge which is allocated to one webpage and a directed edge indicates a hyperlink. The label of the node comes from the title of the webpage. The graph drawing is limited to knowledge within 3 graph distances from noticing knowledge. The graph drawing is opened by just clicking hyperlink on the webpage which you are visiting to study. The noticed webpage is displayed as a red node. In the graph, you can easily recognize some nodes which connect with many other nodes. These nodes indicate very important knowledge which you should know. We can not only easily understand the relation between knowledge through this graph drawing, but also learn basic knowledge and advanced knowledge by just clicking the node in the graph drawing. This graph drawing system enables you to learn STEM efficiently and effectively.

Keywords: STEM, graph drawing, e-learning, hyperlink, knowledge structure

Introduction

The prosperity of the countries strongly depends on the number of the people who are highly educated, especially in the region of STEM (Science, Technology, Engineering and Mathematics). Not only developed countries but also developing countries put a lot of effort into STEM education to survive global and competitive world. The knowledge of STEM has been building up step by step from the basics to the advanced level over a long time and each unit of knowledge is connected with each other in a well-structured form. Well-educated people construct the knowledge structure of STEM in their brain through learning process over a long time. A good understanding of knowledge structure of STEM is necessary for problem solving (Reif & Heller, 1982). But it takes a long time and needs large amount of efforts to acquire knowledge structure. The progress of STEM region is remarkable nowadays and the amount of knowledge that must be learned has been increasing rapidly. Young students must learn more than before to engage in cutting edge technology. Therefore, the method which supports acquiring the knowledge structure quickly and efficiently has been demanded. ICT (Information and Communication Technology) is expected to assist our learning and accelerate learning speed. In general, visualizing knowledge, such as concept mapping is mind mapping known to be an effective method for supporting learners in deal with complex problems (Tergan & Keller, 2005). But there is no visualizing knowledge using hyperlink structure of e-learning website which many people use. We have been developing mathematical e-learning website which was opened to the public since 2004 and is expanded to the fields of physics and engineering recently. More than 10 thousand people access our e-learning website a day mainly through search engine such as Google Search. We have studied visualizing knowledge structure of mathematics based on the hyperlink structure of the mathematics e-learning website to support a construction of knowledge structure for users of our e-learning site (Nakamura, 2014). Our previous visualizing knowledge system has a weak point that it is too complicated to grasp the detail knowledge structure around the knowledge which learner is interested in. To solve this weak point, we developed new visualizing system of knowledge structure based on STEM e-learning website which shows the knowledge structure within 3 graph distances. This system generates the knowledge structure just by clicking a hyperlink on the webpage. It is found that this new system has good characteristics, not only to support a construction of knowledge structure, but also to navigate your way around the e-learning website. We firstly visualize the connections among mathematics, physics and engineering by graph drawing using hyperlink structure of STEM e-learning website.

STEM e-Learning Website

We have been developing e-learning website of mathematics “KIT Mathematics Navigation” (http://w3e.kanazawa-it.ac.jp/math/) since 2004 which have about 2 thousand webpages. Recently we have made learning materials in the field of not only mathematics, but also physics and engineering to learn STEM fields seamlessly. The original website is written in Japanese.

We expound one unit of knowledge in one webpage. Key word or key phrase in description of knowledge is linked to other webpages as a reference if needed. This is a key concept to build the knowledge structure. As a result, hyperlink structure form knowledge structure. Title of webpage should be key word or key phrase which expresses the knowledge described on the webpage for searching. Figure 1 shows an example of webpage.

This framework is very useful to search knowledge by using key word search and to share knowledge by sending hyperlink to the webpage. Learners can make their learning path by just clicking hyperlinks to understand knowledge more, leading self-adaptive learning (Nakamura, 2016; Nakamura, Kudo, & Nishioka, 2016).

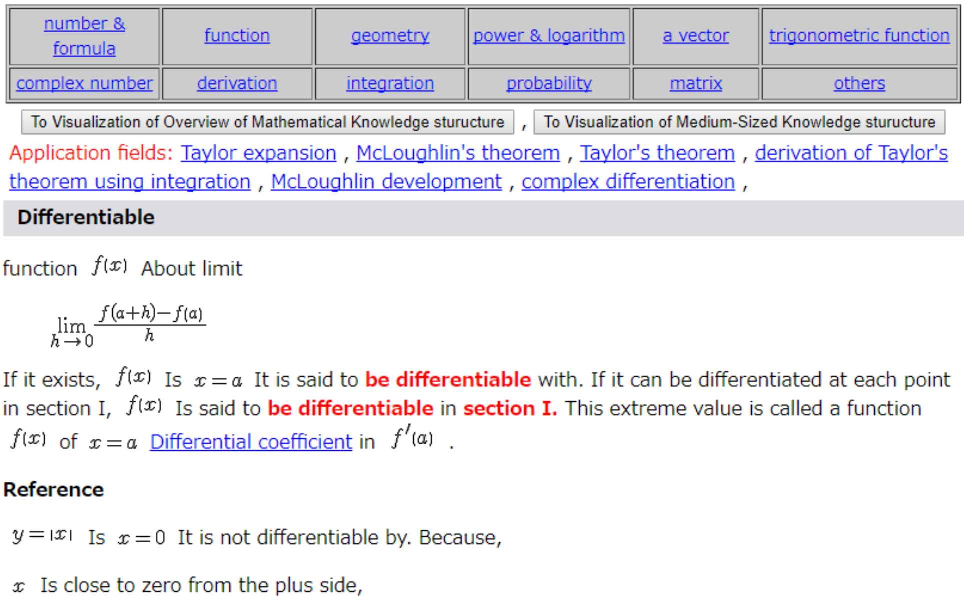

Figure 1. An example of webpage which is translated by Google Translate from Japanese to English

Visualizing System of Knowledge Structure

E-learning website developed according to the framework as mentioned above has hyperlink structure which similar to knowledge structure. We developed the visualizing system of knowledge structure of STEM based on the hyperlink structure of our e-learning website.

Visualization Method

Knowledge structure has a network structure as the units of knowledge are related to each other through hyperlinks. Drawing of network graph is suitable for visualizing the network structure. The website we developed has complicated hyperlink structure because website has not only knowledge, but also menu, exercise, index and so on. Furthermore, each webpage has hyperlinks for navigation. We use the title of the webpage which written between the title tags in the head section of an HTML document as the name of knowledge.

To build a knowledge structure, we needed to extract hyperlinks which are only related to the knowledge structure from all hyperlinks. We made a set of CGI (Common Gateway Interface) programs which run in developing environment. They are as follows. (1) Crawler programs which get data of web addresses, hyperlinks and webpage titles by using PHP and MySQL. (2) Extraction program which extracts the related web addresses and hyperlinks to the knowledge structure from database of MySQL. (3) A program for generating of graph data which form data froms data of web addresses, hyperlinks and webpage titles. (4) Graph display program which is written in Perl. Vis.js (http://visjs.org/) is incorporated into the Perl program. It is a dynamic, browser based visualization JavaScript library for graph drawing and dual licensed under both Apache 2.0 and MIT.

Previously Developed Knowledge Structure of Mathematics

We already developed the knowledge structure of mathematics about three years ago as shown figure 2 (Nakamura, 2015). We used Gephi (https://gephi.org/) and JavaScript GEXF Viewer for Gephi to visualize the network structure of mathematics at that time. Circles which is nodes indicating units of knowledge correspond to webpages. Curves, i.e. edges, between circles indicate hyperlinks between webpages. Clockwise direction of the curve coincides with direction of hyperlinks. Size of circles indicates the importance of knowledge which is referred from many knowledge. In other words, webpage corresponding to the knowledge is linked from many webpages as a reference. We divided hierarchy of mathematics knowledge evenly into 11 parts and allocate each part to each color. 11 colors are 11 gradations from blue to red via green. That is, blue color nodes indicate the most basic level knowledge group, green color nodes indicate mid-level knowledge group and red color nodes indicate the most advanced level knowledge group. We can intuitively know the importance of mathematical knowledge by the size of nodes and the knowledge level of mathematics from the color of nodes. If you click a circle and then click the icon of three dots at lower left, you can get the graph drawing consisted of three types of circles. They are the circle you clicked, circles which correspond to webpages linking to the selected webpage and circles which correspond to webpages linked from the webpage. You can understand the detail knowledge structure around the webpage as shown in fig. 3.

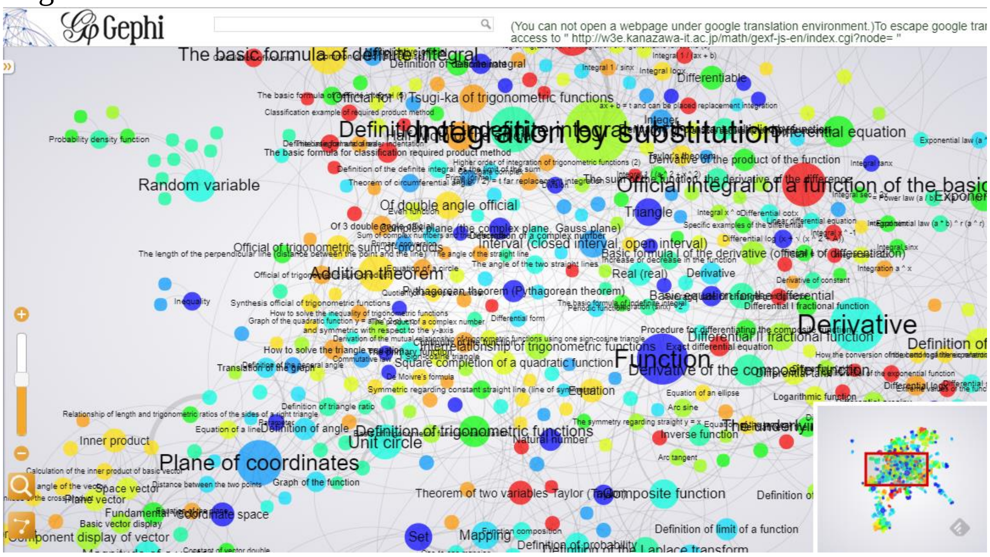

Figure 2. A graph drawing of mathematical knowledge structure
(Retrieved from http://w3e.kanazawa-it.ac.jp/math/gexf-js-en/index.cgi)

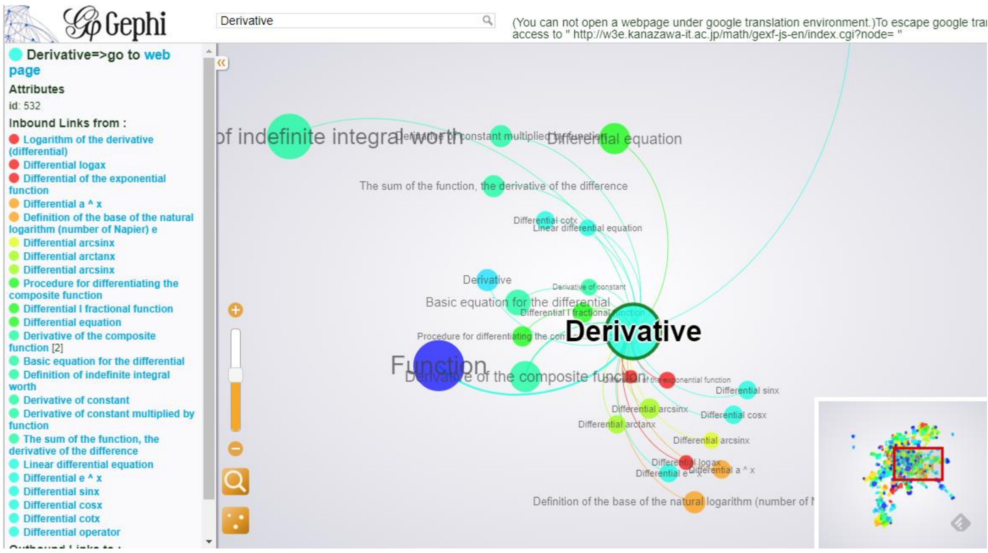

Figure 3. A selected knowledge view of graph drawing of mathematical knowledge structure
(Retrieved from http://w3e.kanazawa-it.ac.jp/math/gexf-js-en/index.cgi?node=/math/category/bibun/doukansuu.html)

New Visualization Method

The graph drawing of knowledge structure in fig. 2 is suitable for grasping overview of knowledge structure. But it is too complicated to understand the knowledge structure in detail. On the other hand, fig. 3 has less information to understand the knowledge structure around focused knowledge. To solve these problems, we developed medium-sized network graph drawing which contains only units of knowledge within 3 graph distances from noticing knowledge as shown in fig. 4. If you click the hyperlink on the top of the webpage, CGI program receives the information of directory of a webpage and generate HTML to display graph drawing. Red elliptical node corresponds to the webpage which you visit just before. Allows are directed links which correspond to hyperlink between webpages. Labels of nodes are titles of webpages.

This medium-sized network graph drawing has two functions. One is as follows. If you click the elliptical node corresponds to knowledge which you want to know, the webpage opens and you can learn the knowledge. This function enables you to learn the relevant knowledge efficiently. For example, you can easily know that the knowledge which many arrows focus on is basic and important knowledge and the knowledge which many arrows go out of consisting of many knowledge. The other is as follows. If you click the elliptical node corresponds to knowledge which you are interested in, you can obtain a new graph drawing whose center is the elliptical node you clicked. This function enables you to explore a detail knowledge structure around knowledge which you are interested in. You can select functions by pushing radio buttons at upper left.

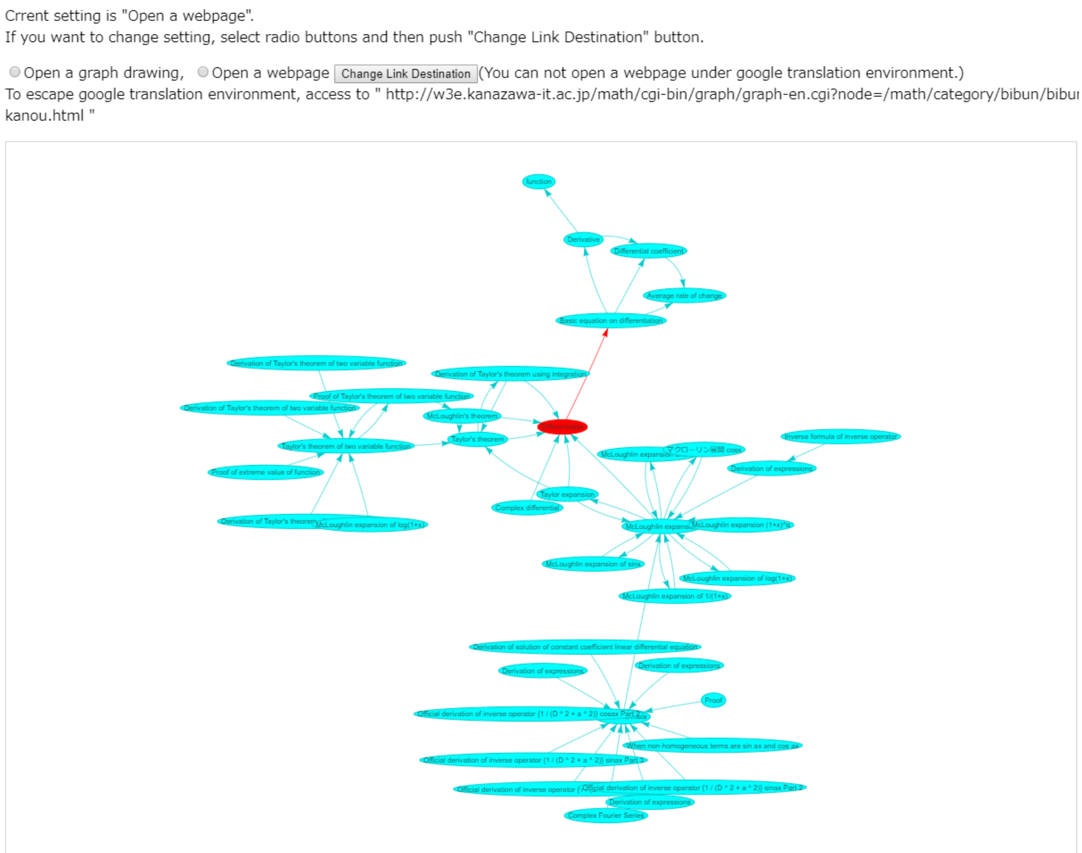

Figure 4. Medium-sized network graph drawing which contains only units of knowledge within 3 graph distances from noticing knowledge.
(Retrieved from http://w3e.kanazawa-it.ac.jp/math/cgi-bin/graph/graph-en.cgi?node=/math/category/bibun/bibun-kanou.html)

We expand the contents of e-learning website form mathematics to STEM. Graph drawing in fig. 5 contains mathematics knowledge, physics knowledge and engineering knowledge. We allocate color according to types of knowledge. A light blue indicates knowledge of mathematics, light green indicates knowledge of high school physics, dark green indicates knowledge of physics and ocher indicates knowledge of engineering. You can understand easily relations between knowledge of STEM fields and learn STEM seamlessly and efficiently.

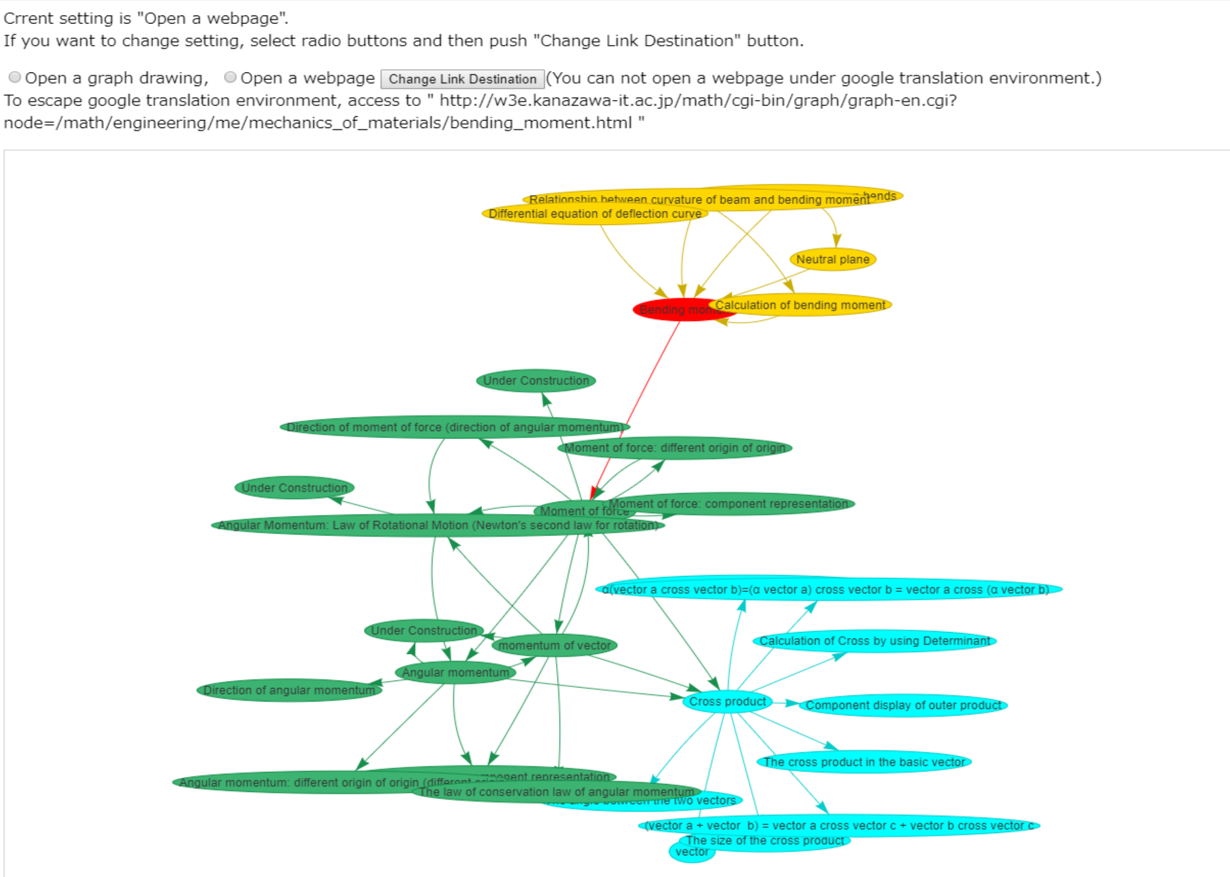

Figure 5. Network drawing contains knowledge of STEM fields (Retrieved from http://w3e.kanazawa-it.ac.jp/math/cgi-bin/graph/graph-en.cgi?node=/math/engineering/me/mechanics_of_materials/bending_moment.html)

Conclusion

We developed medium-sized Network graph drawing which contains units of knowledge within 3 graph distances from noticing knowledge. The graph drawing has two functions. One is for finding knowledge related to noticing knowledge. The other is for exploring the knowledge structure of STEM fields. The developed graph drawing complement weak points of previously developed graph drawing of knowledge structure. By using this graph drawing, you can not only easily understand the knowledge structure of STEM, but also learn STEM fields efficiently and effectively. This method will be applied to other network analysis, such as paper citation network.

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