<<Taikichiro Mori Memorial Research Fund>>
Graduate Student Researcher Development Grant Report

Academic Year 2016

Research Project: A Bipartite Knowledge Representation Model for Critical Thinking and its Evaluation based on Brain Signal Analysis

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1. Research Abstract

This research aims to develop a new representation model of knowledge that augments critical thinking skills. The research is based on three assumptions: (1) understanding is more important than knowing facts; (2) knowledge of reality is relative and dependent on subjective perspectives; and (3) interrelationships between ideas hold the key to improve learners' critical thinking skills.

The research proposes a simple yet effective model to organize ideas from many complex discussions or debates, which is named a NEQA bipartite graph (Never-Ending Question-Answer bigraph) model. Aiding to the model is a set of retrieval and mining functions, which can also be used to develop a real-time collaborative application.

The evaluation of the NEQA bigraph model is based on Electroencephalogram (EEG) signal, a recording of the electrical activity of the brain from the scalp, which is generated during the user's interaction with knowledge representation models. It is believed that the use of neuro-technologies in usability evaluation brings forth a more objective assessment of knowledge modeling studies.

2. Research Activities and Results

2.1. Bipartite Graph Knowledge Representation Model

The nature of debating or dialogic discussion is exchanging arguments by questions and answers in which corresponding to one question, there may be many answers from many agents who have different perspectives to the question; then from each answer there will be many other questions that require to be clarified. Based on this observation, this research proposes to use bipartite graphs (or digraphs) to model flows of debates or dialogues. A bipartite graph that has two disjoint vertex sets that are question and answer sets. Every edge connects a question to an answer holds an evidence for the answer and every edge connects an answer to a question holds an argument raised from the answer. Figure 1 shows the overall illustration of the NEQA bigraph model whereas Figures 2, 3, 4 show concrete examples of bigraphs for different use case scenarios.

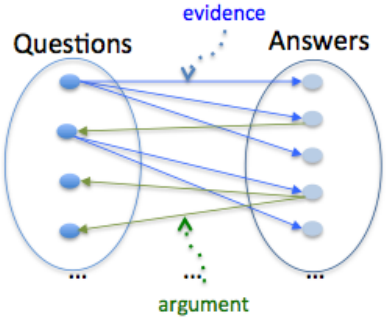

Figure 1. The proposed NEQA bigraph model for knowledge representation.

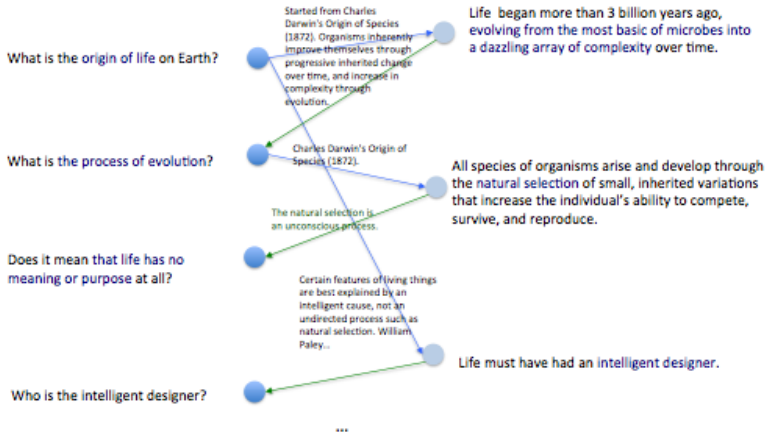

Figure 2. A sample NEQA bigraph of evolution theory debate with flows of ideas.

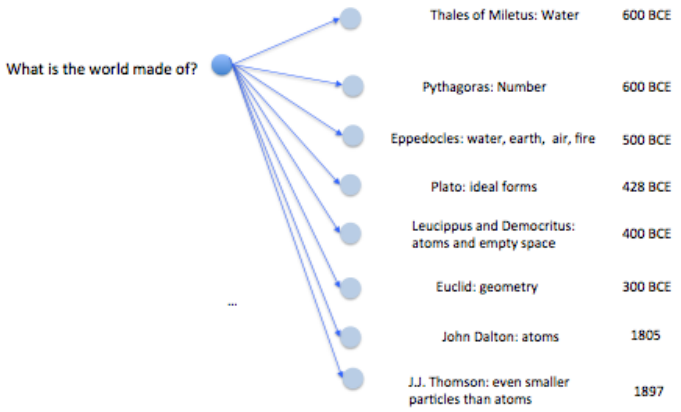

Figure 3. Using the proposed NEQA bigraph model to represent and contrast ideas by timeline.

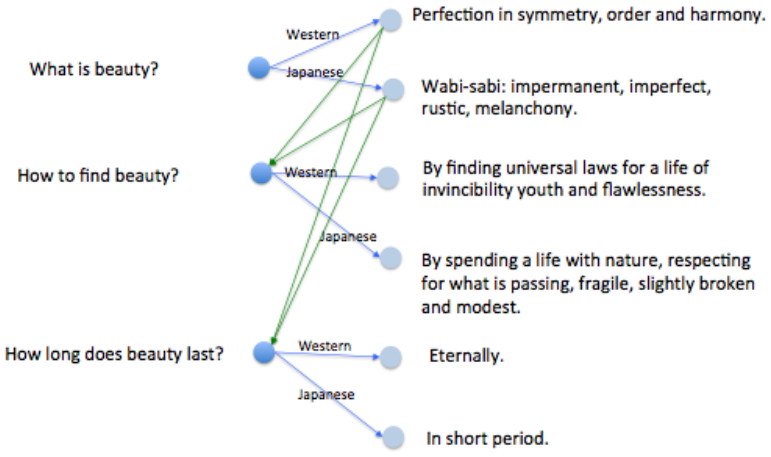

Figure 4. Using the proposed NEQA bigraph to represent and compare cross-cultural ideas.

The proposal of the NEQA bigraph model and its functionality was presented in the following international conference:

Diep Thi Ngoc Nguyen and Yasushi Kiyoki, "A Bigraph Representation Model and Directional Search Mechanism for Debates," *18th International Electronics Symposium (IES)*, Bali, Indonesia, September 29 – 30, 2016, (accepted 6 pages, added to IEEE Explore in Jan. 2017).

2.2. EEG-based Brainwaves and Brain Activities

It is known that when a person is in a certain state of body-mind, a specific type of waves is released indicating the brain activity [1]. Table 1 summarizes the brainwave types and their descriptions with range of signal frequencies using an EEG device.

Table 1 Type of brainwaves and their descriptions.

Type of brainwave	Frequency range	Levels of activity
Delta	1 – 4 Hz	Deep, dreamless sleep
Theta	4 – 8 Hz	Dreaming sleep, deep relaxation, meditation
Alpha	8 – 14 Hz	Abstract thinking, self-controlling, relaxation
Beta	14 – 30 Hz	Logical thinking, awake, concentration, problem-solving
Gamma	30 – 170 Hz	High alerted, working with and memorizing different information

2.3. Knowledge System Evaluation Architecture

Figure 5 describes the overall architecture for a knowledge system evaluation based on EEG neurofeedbacks. Current modern technologies provide many tools to capture the brain activities of users in a non-invasive way. In this research, the OpenBCI [2] sensing devices are used.

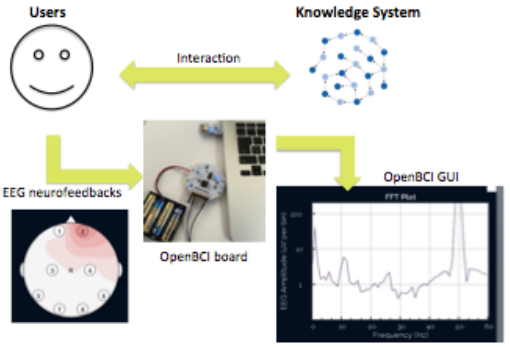

Figure 5. Overall architecture for knowledge system evaluation using EEG neurofeedback.

2.4. Experimental Studies

Using the OpenBCI 8-channel board, two knowledge systems are evaluated. The first is the text-based model and the second is based on the proposed NEQA bigraph model. Figures 6, 7 show the representative brain activities of users when interacting with each knowledge system. We can see in Figure 7 the higher levels of brain activities in all range of frequencies, but many peaks at Beta and Gamma rhythms. This indicates the higher levels of concentration and critical thinking when interacting with the NEQA knowledge model. Contrastingly, in Figure 6, although the Gamma rhythm is high (it is reasonable since the user is interacting with a new knowledge text), other rhythms are low but with some peaks at Theta and Alpha rhythms. This can indicate a “sleepy” mode or a relaxing mode.

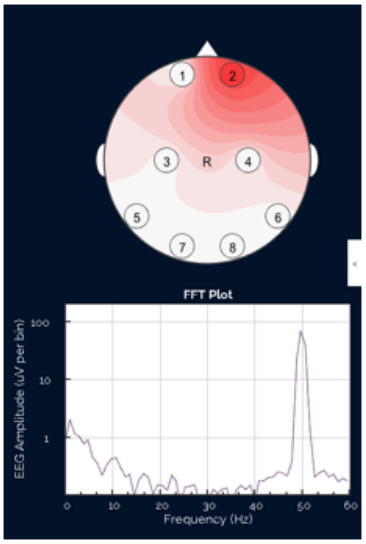

Figure 6. Typical brainwave graph when interacting with text-based knowledge.

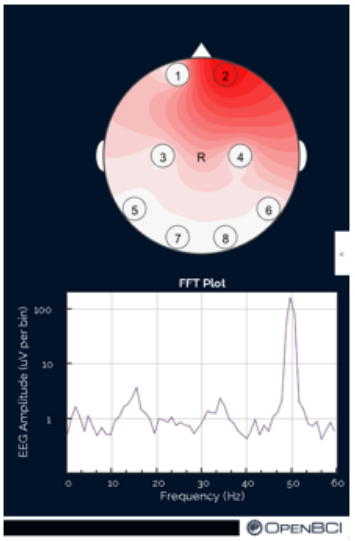

Figure 7. Typical brain activity when interacting with the proposed NEQA knowledge bigraph.

The above sample experiments above suggest a great effectiveness of the proposed NEQA knowledge representation model for accelerating critical thinking of users. While the proposal is ambitious in computation, it is very promising as a new objective method to investigate user experience.

3. Work on progress:

- Automatic HCI understanding when interacting with knowledge systems.
- Intensive experimental studies.
- Using neurofeedbacks to alter knowledge system to accelerate critical thinking.

4. References:

[1] Alfimtsev, A. N., Basarab, M. A., Devyatkov, V. V., & Levanov, A. A. (2015). A New Methodology of Usability Testing on the Base of the Analysis of User's Electroencephalogram. *Journal of Computer Sciences and Applications*, *3*(5), 105-111.

[2] Open source Biosensing Tools, OpenBCI, http://openbci.com/.