Explanation of the Network Analysis used in *Human Survivability Studies*

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Introduction

In this book, we used the data science technique of text mining to process natural language, the results of which have been used to display the text as a network. On this basis, community analysis, a network science technique, has been conducted to extrapolate network characteristics. In particular, the relationships between the global issues discussed in *Human Survivability Studies*, those between the fields of study (sciences) that tackle these issues and those between global issues and science have been clarified. Finally, we presented the characteristics of Human Survivability Studies as 'collective intelligence', i.e. the amalgamation of Human Survivability Studies as interpreted by the authors of this book.

Morphological analysis

Here, the technique of text mining will first be explained, with particular focus on morphological analysis. In this form of analysis, text (unstructured data) is divided into individual words. By aggregating which words are used and how often, we can analyze the text statistically.

As an example, we subject the following text consisting of the two sentences to morphological analysis: 'In the midst of various sciences, Human Survivability Studies represents the latest collective intelligence. Collective intelligence has validity for the purpose of research on global issues'. These sentences have been broken down into the sequences of words shown in quotation marks below.

1st Sentence
'In (preposition)' + 'the (particle)' + 'midst (noun)' + 'of (preposition)' + 'various (adjective)' + 'sciences (noun)' + ', (punctuation)' + 'Human Survivability Studies (noun phrase)' + 'represents (verb)' + 'the (particle)' + 'latest (adjective)' + 'collective intelligence (noun phrase)' + '. (punctuation)'

2nd Sentence
'Collective intelligence (noun phrase)' + 'has (verb)' + 'validity (noun)' + 'for (preposition)' + 'the (particle)' + 'purpose (noun)' + 'of (preposition)' + 'research (noun)' + 'on (preposition)' + 'global issues (noun phrase)' + '. (punctuation)'

Here, the '+' symbol indicates that each word in a sequence belongs to the same sentence. Next, the nouns and noun phrases will be extracted from these sequences.

1st Sentence
'midst (noun)' + 'sciences (noun)' + 'Human Survivability Studies (noun phrase)' + 'collective intelligence (noun phrase)'

2nd Sentence
'collective intelligence (noun phrase)' + 'validity (noun)' + 'purpose (noun)' + 'research (noun)' + 'global issues (noun phrase)'

By treating these nouns as nodes and making links between nodes in the same sentence, these sequences of nouns and noun phrases can be expressed as a network.

'midst' – 'sciences'
'midst' – 'Human Survivability Studies'
'midst' – 'collective intelligence'
'sciences' – 'Human Survivability Studies'
'sciences' – 'collective intelligence'
'Human Survivability Studies' – 'collective intelligence'
'collective intelligence' – 'validity'
'collective intelligence' – 'purpose'

‘collective intelligence’ – ‘research’
‘collective intelligence’ – ‘global issues’
‘validity’ – ‘purpose’
‘validity’ – ‘research’
‘validity’ – ‘global issues’
‘purpose’ – ‘research’
‘purpose’ – ‘global issues’
‘research’ – ‘global issues’

Here, the symbol ‘–’ signifies a link. The first six links indicate relationships in the first sentence, the remaining ten those in the second sentence. Here, it should be noted that the text comprising the two sentences is expressed as a single network. The ‘collective intelligence’ node is linked to the ‘Human Survivability Studies’ node belonging to the first sentence and to the ‘validity’, ‘purpose’, ‘research’ and ‘global issues’ nodes of the second sentence, and is therefore a node that bridges the two sentences.

Glossaries

Next, text mining using a glossary will be explained. In this analysis, the only attributes are ‘global issues’ and ‘science.’ Before the analysis, a glossary recording the attributes of nouns forming nodes will be created, as shown below.

Global issues
‘global issues (field A)’

Science
‘sciences (field a)’
‘research (field b)’
‘collective intelligence (field c)’
‘Human Survivability Studies (field c)’

The three nouns – ‘midst’, ‘validity’ and ‘purpose’ – are not included in either glossary. Using the two glossaries, the following networks consisting of nodes given the attributes of ‘global issues’ or ‘science’ are obtained.

'sciences (Science: field a)' – 'Human Survivability Studies (Science:)'
'sciences (Science: field a)' – 'collective intelligence (Science: field c)'
'Human Survivability Studies (Science:)' – 'collective intelligence (Science: field c)'
'collective intelligence (Science: field c)' – 'research (Science: field b)'
'collective intelligence (Science: field c)' – 'global issues (Global issues: field A)'
'global issues (Science:)' – 'research (Science: field b)'

The glossaries for global issues and sciences used in the actual analysis were created by asking the authors of each chapter to name ten keywords for each attribute of 'global issues' and 'sciences' used in their chapter, and to designate their attributes (Global issues / Science: Fields) and then collect those attributes and keywords from the book as a whole. Here, the authors were asked to designate fields for 'global issues' and 'sciences' from options prepared in advance. At the same time, these keywords were also used as index keywords after removing the attributes (Global issues / Science: Fields). As an example, a glossary for global issues in Chapter Six is shown in Table A.1 and a glossary for sciences in Table A.2.

The same procedure was repeated for all sentences in the book to express the whole book as a network. To make the network map easier to read, the respective networks for global issues and sciences were shown separately, and attention was paid only to links between nodes with large numbers of links between the two networks.

Community analysis of networks

Finally, the network science technique of community analysis will be carried out and network characteristics extrapolated. Community analysis is a method of extracting parts that are closely linked in a network by maximizing the modularity function. Here, the modularity function is defined as the difference between the total number of links made between nodes belonging to the same community, and the total number of links between nodes belonging to the same community in

Table A.1: Glossary of global issues

Keywords	Field of global issues
Globalization	International relations
Business cycle	Economic growth
Economic growth	Economic growth
International trade	Economic disparity
Economic shock	Economic growth
Greenhouse gas	Climate change and natural disaster
Climate change	Climate change and natural disaster
Energy security	Energy security
International organization	International relations
Economic disparity	Economic disparity

Table A.2: Glossary of sciences

Keywords	Field of science
Econophysics	Multidisciplinary field
Data analysis	Informatics
Synchronization	Mathematical and physical sciences
Hilbert transform	Mathematical and physical sciences
Renewable energy	Environmental science
Output fluctuation	Environmental science
Principle of maximum entropy production	Mathematical and physical sciences
Meta-analysis	Informatics
Complex network	Social science
Community	Social science

which links have been made at random so as to preserve the order. To find the community division that maximizes the modularity function, we start first from a state in which each node corresponds to a single community. We remove two from the total of all communities and calculate the modularity function on the assumption of a single community. We calculate the modularity function for all combinations, and adopt the combination in which the value of the modularity

function is largest. We repeat this procedure, and finish the calculation when the modularity function stops increasing. In this way, we obtain the community division that maximizes the modularity function. On the network maps, nodes inside the shaded fields surrounded by the closed curves belong to the same community.

What can be read from the various networks

1. Network map of Human Survivability Studies
Human Survivability Studies are collective knowledge structured such that the scientific disciplines surround the liberal arts disciplines positioned in the center.

2. Part I network map
Global issues: Economic growth, ethics for life and the environment, climate change and natural disaster
Science: Physics and mathematics, medicine, dentistry and pharmaceutical sciences, humanities
Relationship between global issues and science: Survival – essence, Snowball Earth – habitable zones, human beings – procaryotes, cooling – history

3. Part II network map
Global issues: Ethics for life and the environment, economic growth, energy security
Science: Social science, physics and mathematics, multidisciplinary fields
Relationship between global issues and science: Poverty – evolutionary economics, human beings – meta-analysis, poverty – information technology

4. Part III network map
Global issues: Ethics for life and environment, economic disparity, poverty
Science: Engineering, humanities, social science, medicine, dentistry and pharmaceutical sciences
Relationship between global issues and science: Human beings – oceans, United Nations – international studies, economic growth – human capital theory, humanity – cholera, population growth – environmental pollution, human beings – energy saving

5. Part IV network map
Global issues: International relations, climate change and natural disaster, ethics for life and the environment
Science: Engineering, social science, humanities and social sciences
Relationship between global issues and science: International cooperation – gender, globalization – development assistance, human beings – market risk

6. Part V network map
Global issues: Ethics for life and the environment, economic growth, forest destruction
Science: Social science, agriculture, humanities
Relationship between global issues and science: Food – oceans, international law – international law, environment – forests, living beings – induction

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