Chapter 12
Artificial Intelligence IQ Test

Since 2015, "artificial intelligence" has become a popular topic in science, technology, and industry. New products such as intelligent refrigerators, intelligent air conditioning, smart watches, smart robots, and of course, artificially intelligent mind emulators produced by companies such as Google and Baidu continue to emerge. However, the view that artificial intelligence is a threat remains persistent. An operation is that if we compare the developmental levels of artificial intelligence products and systems with measured human intelligence quotients (IQs), can we develop a quantitative analysis method to assess the problem of artificial intelligence threat?

Quantitative evaluation of artificial intelligence currently in fact faces two important challenges: there is no unified model of an artificially intelligent system, and there is no unified model for comparing artificially intelligent systems with human beings. These two challenges stem from the same problem, namely, the need to have a unified model to describe all artificial intelligence systems and all living behavior (in particular, human behavior) in order to establish an intelligence evaluation and testing method. If a unified evaluation method can be achieved, it might be possible to compare intelligence development levels.

This chapter provides an innovative concept and basic measurements on testing the Intelligence Quotient (IQ) on artificial intelligence (AI) technologies and devices. Section 12.1 describes the basic concepts of IQ test on AI, particularly Internet search engines and a standard intelligence model. Section 12.1.1 builds an IQ test bank to compare the known search engines, such as Google and Baidu with three groups of Children whose ages are 6, 12, 18 [1]. Section 12.1.2 further employs a data mining method to find out the features of search engines reflected in the Internet intelligence test and the intelligence difference between search engines and human beings [2]. Section 12.1.3 proposes a "standard intelligence model" that unifies AI and human characteristics in terms of four aspects of knowledge, i.e., input, output, mastery, and creation [3]. Section 12.2 investigates three laws of intelligence for interpreting the concepts of intelligence, wisdom, consciousness,

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life and non-life [4]. Section 12.3 explores characteristics on AI-IQ test by using fuzzy cognitive map-based dynamic scenario analysis [5].

12.1 A Basic AI-IQ Test

This subsection introduces the IQ test concepts of Internet, which are IQ of Internet applications, Internet 2014 Intelligence Scale, Internet IQ absolute and then explore deviation algorithms for carrying out the IQ test for the major Internet search engines with a group of Children's IQ.

12.1.1 The Concepts of AI-IQ Test

Definition 12.1 IQ of Internet application is to measure intellectual development level of Internet applications at certain test time through a series of standard tests, which include electronic bullet board, search engine, social network, electronic mailbox and instant messaging software etc.

Definition 12.2 Internet IQ is to measure Internet IQ Standards Evaluating Bank through a series of standard tests, so as to derive the intellectual development level of Internet at certain test time, and intellectual development level of Internet is also termed as Internet IQ at that point of time [6].

Based on the basic understanding that intellectual is about people's ability of understanding objective things and applying knowledge to solve practical problems, we will build Internet Intelligent Evaluation System from four major aspects in terms of knowledge obtaining ability (also termed as observation ability) and retaining ability, together with ability of knowledge innovation and feedback (also termed as expression ability), set up 15 subtests from the four aspects and endow weights with Delphi Method to form 2014 Internet Intelligence Scale as shown in Table 12.1.

Definition 12.3 Based on the structure of Table 12.1, the Absolute IQ Algorithm of Internet (IQA) is given as:

$$\mathrm{IQA} = \sum_{i=1}^{N} \mathrm{Fi} \times \mathrm{Wi} \tag{12.1}$$

Where Fi is the evaluation index score (adopts the indexes of Table 12.1), Wi is the weight of evaluation index, and N is the number of evaluation index.

Table 12.1 2014 Version of Internet Intelligence Scale

First-class Index	Second-class Index	Description	Weight (%)
Ability of knowledge acquisition	Ability of character acquisition	Know about the testing object whether can understand and answer the testing question via characters. (Only one correct answer can be deemed pass)	3
	Ability of sound acquisition	Know about the testing object whether can understand and answer the testing question via sounds. (Only one correct answer can be deemed pass)	3
	Ability of picture acquisition	Know about the testing object whether can understand and answer the testing question via pictures. (Only one correct answer can be deemed pass)	4
bility of mastery of knowledge	Common knowledge	Know about the knowledge range of testing object. For example: *what's the name of three kinds of blood vessel for a human body?*	6
	Translate	Know about the testing object's transfer ability of the different languages. For example: *please translate "Machine Intelligence cannot exceed that of human beings" into English.*	3
	Calculate	Know about the calculation ability of the testing object, calculation speed and correctness. For example: *what is the result for 356*4 − 213?*	6
	Put in order	To know about the systemizing ability for the matters' relationship. For example: *please rank the commander, platoon leader, group commander, monitor, battalion commander, regimental commander by position.*	5
Ability of knowledge innovation	Associate	Know about the ability of observing similarities for the testing object. For example: *foot as for hand, is equivalent to leg as for what?*	12
	Create	Know about the ability of second creation according to the files. For example, *please tell a story with the key words of sky, rainbow, panda, mountain, hunter and so on.*	12
	Speculate	Know about the ability of speculating described things. *For example, there is one kind of animal that is similar to wolf, but is called as loyal friend of human being, then what is it?*	12%
	Select	Know about the testing object whether can select the same or different matter's relation. For example: *please select the different one among snake, tree and tiger.*	12
	Discover (laws)	Know about the testing object whether can discover the laws and apply them from the information or not. For example: *what is the figure after 1,2,4,7,11,16?*	12

(continued)

Table 12.1 (continued)

First-class Index	Second-class Index	Description	Weight (%)
Ability of feedback of knowledge	Ability of expressing via characters	Know about the testing object whether can express the testing results with characters. (Only one correct answer can be deemed pass)	3
	Ability of expressing via sounds	Know about the testing object whether can express the testing results with sounds. (Only one correct answer can be deemed pass)	3
	Ability of expressing via pictures	Know about the testing object whether can express the testing results with pictures. (Only one correct answer can be deemed pass)	4

Definition 12.4 Similarly, the deviation IQ Algorithm of Internet (**IQd**) can be expressed as:

$$\mathbf{IQd} = \mathbf{100} + \frac{\mathrm{IQ_A}\text{-}\overline{\mathrm{IQ_A}}}{S} \tag{12.2}$$

This formula is suitable for the IQ comparison among all the applications of Internet, highlighting the Internet testing object's position in Internet application. Under this circumstance, $\mathrm{IQ_A}$ is the average value of all applicative IQ in the Internet IQ evaluating bank (Table 12.1).

Let S be the standard deviation of all application in the Internet IQ evaluating bank, M is the number of all applications in the Internet IQ evaluating bank.

$$\mathrm{S} = \sqrt{\frac{1}{\mathrm{M}}\sum_{\mathrm{i}=1}^{\mathrm{M}}\left(\mathrm{IQ_A}\text{-}\overline{\mathrm{IQ_A}}\right)^2} \tag{12.3}$$

Search engine is one of the most important applications of Internet, whose representatives are Google, Baidu and Bing, etc. The working principle of search engine can automatically access to Internet with the help of a systematic procedure called Spider which can collect the web pages automatically [7]. The Spider can climb to other web pages along with all the URLs from any web pages. It repeats this process, and collects all the web pages it has climbed over. Then the system analyzes the collected web pages with the procedure of analysis index from the index database, extracts relevant web information according to certain correlation algorithm with a number of complex computations. After that it obtains the relevance or importance of the page content and hyperlinks from each key word of each web page [8].

When a user inputs a keyword search in the search rankings of an index database, the searching systematic procedure finds out all the related web pages. In the end, the system of page generating returns the page links and page abstracts of searching results to the user [9].

Google, Baidu and other types of search engines are improving the levels of intelligent search engines currently in a variety of ways to continuously, from only being able to identify texts to identify sounds and pictures. Through introducing "semantic understanding" technology, they try to understand the user's search intention and the computing arithmetic and structured display of searching results would be re-optimized, which would present the most accurate and comprehensive information to the user. With the help of deep learning, search engines are made to identify what the object is by the image automatically [10]. So according to the rules established by the Internet earlier IQ tests, the choice of IQ tests on search engines will have important significance.

According to Table 12.1, the following search engines IQ test question bank can be built. Based on the characteristics of different abilities, there are respectively one test question for the ability to obtain the knowledge and gain feedbacks, four questions for the ability to grasp knowledge and innovate it. With more in-depth study of the future, it will increase the number of test questions in order to improve the accuracy of the test.

The question bank for search engines is named *the 2014 version of the search engine intelligence test question bank*. The components are described as:

A. Ability of character acquisition

1. Use the input tool provided by the search engine, see whether one can input the character string "1 + 1 =?" and feedback the correct result or not.

B. Ability of sound acquisition

1. Tester reads "1 + 1 =?", check the input tool provided by the search engine can identify the correct result whether or not.

C. Ability of picture acquisition

1. Tester draws "1 + 1 =?" on a paper, check the input tool provided by the search engine can identify the correct result whether or not.

D. Ability of grasping the common knowledge

1. Which river is the longest in the world?
2. Which planet is the largest in the solar system?
3. How many chromosomes in human body?
4. What's the name of the first president of USA?

E. Ability of grasping the translation

1. Translate "力量(Liliang)" into English
2. Translate "力量(Liliang)" into Japanese
3. Translate "力量(Liliang)" into French
4. Translate "implications" into Chinese

F. Ability of grasping the calculation

1. How much is 25 multiply by 4?
2. How much is 36 divide 3?
3. How much is the biquadrate of 2?
4. How much is 128 extract three roots?

G. Ability of grasping the ranking

1. Please rank 34, 21, 56, 100, 4, 7, 9, 73 from small to large.
2. Please rank undergraduate, elementary student, middle school student, doctor, master from high education background to low education background.
3. Please rank Europe, the earth, France, Paris, Eiffel Tower from large to small via the area.
4. As for the same weight, please rank the price from expensive to low for gold, copper, silver, stone.

H. Ability of grasping the selection

1. Please select a different one from snake, tree, tiger, dog and rabbit.
2. Please select a different one from the earth, Mars, Venus, Mercury and the sun.
3. Please select a different one from red, green, blue, golden, yellow and white.
4. Please select a different one from car, train, airplane, steamer, and worker.

I. Ability of grasping the association

1. If associate birds with the sky, what can be associated with fishes?
2. If associate the son with the father, what can be associated with daughter?
3. If associate red with the sun, what can be associated with blue?
4. If associate the primary student with the primary school, what can be associated with universities?

J. Ability of grasping the creation

1. Please tell us a story by sky, rainbow, panda, mountain, and hunter and so on.
2. Please tell us a story by China, America, Russia and Japan.
3. Please tell us a story by red, tree, airplane, bullet, sun and so on.
4. Please tell us a story by 1, 2, 3, 4, 5.

K. Ability of grasping the speculation

1. If most of people are holding umbrellas in the street, with dropsy on the ground, then what is the weather like at this time?
2. If one person wears high-heeled shoes, skirt, and with long hair, then what is the sex for this person probably?
3. If there are many animals in one place, but all in the cages, and many people are looking, then where is it?
4. If one person throws off his pen, but just float away around him, then where is he probably?

L. Ability of grasping the discovery of laws

1. Offer four questions, respectively are: $20/5 = 4$, $40/8 = 4$, $80/20 = 4$, $160/40 = 4$, observe the rules, then design the fifth question.
2. Cook A expresses that he likes to eat pork, mutton, beef, chicken, fish, but does not like Chinese cabbage, cucumber, green been, eggplant, potato, the please observe the rules, select the favorite food between duck meat and celery for this Cook.
3. On a certain regulation, the row numbers are $\frac{1}{2}, \frac{1}{3}, \frac{1}{10}, \frac{1}{15}, \frac{1}{26}, \frac{1}{35} \ldots$ for this rule, what is the seventh one in this series?
4. At every night, Company staff B goes home on Jan. 1st, goes the bar on Jan., 2nd, goes home on Jan. 3rd, goes the bar on Jan. 4th, goes home on Jan. 5th, goes the bar on Jan. 6th, goes home on Jan. 7th, goes the bar on Jan. 8th, where B may present on Feb. 13th probably?

M. Ability of expressing via characters

1. Input the character string "How much is 1 plus 1, please answer via characters", check the testing search engine whether can express the answer via characters or not.

N. Ability of expressing via sounds

1. Input the character string "How much is 1 plus 1, please answer via sounds", check the testing search engine whether can express the answer via sounds or not.

O. Ability of expressing via pictures

1. Input the character string "How much is 1 plus 1, please answer via pictures", check the testing search engine whether can express the answer via pictures or not

12.1.1.1 A Small Sample of AI-IQ Test

For an experimental study of IQ test on search engine, 7 well-known search engines: Google.com.hk, Baidu.com, Sogou.com, Bing.com, Zhongsou.com, panguso.com, so.com are chosen as the samples of search engine to conduct the IQ test. The testing principle is to carry out the testing via Table 12.1 with regard to the whole testing questions. If one cannot input the question into the testing search engine, this score will be 0, and if one can input the question into the search engine, which cannot shows the correct results in the first try or the time of answering is over 3 min in the first search engine, the score will be 0. According to the rules of 2014 Internet Intelligent Scale, in the test 1, 2, 3 and 13, 14, 15, there is only one question, if one can answer correctly in 3 min, each question can get 100; as for other testing, if one can answer correctly in 3 min, each question may get 25. The testing environment is Winxp System, IE9 explorer (Chinese version). The testing results are shown as Table 12.2.

Then, we carry out the IQ test for 20 Children of 6 ages, 12 ages and 18 ages via the same rules, and obtain the results as in Table 12.3.

According to the weight rules of Table 12.1, the absolute IQ and relative IQ scores for 7 search engines and 20 children of 3 different ages are calculated as in Table 12.4 (note that the absolute IQ's full mark is 100).

12.1.2 A Data Mining for Features of AI-IQ Test

12.1.2.1 A Large Sample of AI-IQ Test

Based on the above discussion, a data mining method is applied to find out the features of search engines reflected in the Internet intelligence test and the intelligence difference between search engines and human beings.

Table 12.2 Results of Seven search engines IQ Test

	Google	Baidu	Sogou	Bing	so	panguso	Zhongsou	Weight (%)
Ability of character acquisition	100	100	100	100	100	100	100	3
Ability of sound acquisition	0	0	0	0	100	0	0	3
Ability of picture acquisition	0	100	100	0	100	0	0	4
Common knowledge	100	100	100	100	100	75	50	6
Translate	100	75	50	50	50	0	0	3
Calculate	**100**	**100**	100	**25**	**75**	**75**	**50**	6
Put in order	0	0	0	0	0	0	0	5
Association	0	0	0	0	0	0	0	12
Create	0	0	0	0	0	0	0	12
Speculate	0	0	0	0	0	0	0	12
Select	0	0	0	0	0	0	0	12
Discover (laws)	0	0	0	0	0	0	0	12
Ability of expressing via characters	100	100	100	100	100	100	100	3
Ability of expressing via pictures	0	0	0	0	0	0	0	4

In order to show the meaning of the data mining method, 50 typical search engines across the world are first tested by the scale of Table 12.1. They include Google, Baidu, Bing, eMaxia, Anzswers, Pictu, Saja search, and 1stcyprus from 25 countries and regions, including China, America, India, the United Kingdom, Russia, Japan, Australia and so on. If any question in the test bank cannot be entered into a search engine, zero score will be given to the search engine. If a question can be entered into a search engine, but the correct result is not included in the first search result, or the time spent on answering the question is more than 3 min, zero score should be given to the search engine, too. According to the 2014 Internet Intelligence Scale, there is only one question in test items 1, 2, 4, 13, 14 and 15, if a correct answer is given within 3 min, a score of 100 may be obtained by each. And for the questions in other test items, if they are answered correctly by a search engine within 3 min, a score of 25 may be given to that search engine. The test environment is WinXP system and IE9 browser (Chinese version). The test results are shown in Table 12.5. Meanwhile, the same rules are used to test 150 people who are grouped by the age of 6, 12 and 18, 50 people for each group in Table 12.6.

According to the weight rules of Table 12.1, the Absolute IQs and the Relative IQs of the 50 search engines and three groups of people are calculated and the

Table 12.3 Results of 20 children IQ Test

	6 Ages (average value)	12 Ages (average value)	18 Ages (average value)
Ability of character acquisition	100	100	100
Ability of sound acquisition	100	100	100
Ability of picture acquisition	100	100	100
Common knowledge	25	25	75
Translate	0	25	50
Calculate	**25**	**75**	**100**
Put in order	50	75	100
Association	50	75	100
Create	50	100	100
Speculate	75	100	100
Select	50	100	100
Discover (laws)	25	75	100
Ability of expressing via characters	100	100	100
Ability of expressing via sounds	100	100	100
Ability of expressing via pictures	100	100	100

results are ranked in a descending order, as shown in Table 12.7. Note that the K values were respectively taken as 3, 4 and 5, the clustering results within the cluster sum of squared errors were respectively 23.5, 13.4 and 9.6. The clustering results within the cluster sum of squared errors were respectively 23.5, 13.4 and 9.6.

Clustering Analysis

Firstly, in order to obtain the referable relationship between the 53 test objectives and the 15 test items, all the 795 pieces of test data in Tables 12.5 and 12.6 are analyzed in the software weka 3.6 by using the K-means clustering algorithm. It respectively takes K values as 3, 4, and 5. When the K value is chosen as 3; the search engines are classified as a, b, and c. Similarly, when the K value is chosen as 4, the search engines are classified as a, b, c, and d; and when the K is equal to 5, the clusters are denoted as a, b, c, d, and e. The clustering results of search engines depending on the K values which are also shown in Table 12.7.

Classification Analysis

As we know, there is no good evaluation criterion for a typical clustering problem. In order to evaluate the effectiveness of clustering result, we employ various classification algorithms on labeled data. Then, the evaluation of classification results can be seen as an indirect evaluation for clustering result. Consequently, in this part, according to the clustering result obtained in the above part, classification

Table 12.4 Absolute IQ/relative IQ scores

	Google	Baidu	Sogou	Bing	so	panguso	Zhongsou	6 Ages	12 Ages	18 Ages
Absolute IQ	21	24.25	23.5	15	25	15	12	55.5	85.25	97
Relative IQ	99.34	99.44	99.43	99.14	99.48	99.14	99.04	100.51	101.53	101.92

Table 12.5 Results of Seven search engines IQ Test

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
China	Baidu	100	0	100	100	50	100	0	0	0	0	0	0	100	0	0
China	Sogou	100	0	100	75	50	100	0	0	0	0	0	0	100	0	0
China	so	100	100	100	75	50	75	0	0	0	0	0	0	100	0	0
China	panguso	100	0	0	75	0	75	0	0	0	0	0	0	100	0	0
China	Zhongsou	100	0	0	50	0	50	0	0	0	0	0	0	100	0	0
Hong Kong	timway	100	0	0	75	25	25	0	0	0	0	0	0	100	0	0
Greece	Gogreece	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Holland	slider	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Norway	Sunsteam	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Egypt	yell	100	100	100	50	50	50	0	0	0	0	0	0	100	0	0
Egypt	netegypt	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
USA	yahoo	100	0	0	75	100	0	0	0	0	0	0	0	100	0	0
USA	Dogpile	100	100	0	0	0	0	0	0	0	0	0	0	100	0	0
USA	google	100	100	100	75	100	100	0	0	0	0	0	0	100	0	0
USA	bing	100	0	0	75	50	25	0	0	0	0	0	0	100	0	0
Solomons	eMaxia	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Australia	Anzswers	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Australia	Pictu	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Malaysia	Sajasearch	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
New Zealand	SerachNZ	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
India	indiabook	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
India	khoj	100	0	0	75	0	0	0	0	0	0	0	0	100	0	0
Britain	ask	100	0	0	75	50	0	0	0	0	0	0	0	100	0	0

Britain	Excite UK	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Britain	splut	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
France	voila	100	0	0	75	50	0	0	0	0	0	0	0	100	0	0
France	lycos	100	0	0	100	0	0	0	0	0	0	0	0	100	0	0
Russia	Yandex	100	0	100	100	100	0	0	0	0	0	0	0	100	0	0
Russia	ramber	100	100	0	75	100	25	0	0	0	0	0	0	100	0	0
Russia	webalta	100	0	0	75	100	0	0	0	0	0	0	0	100	0	0
Russia	Rol	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Russia	Km	100	0	0	75	0	0	0	0	0	0	0	0	100	0	0
Spain	ciao	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Spain	His	100	0	0	100	50	75	0	0	0	0	0	0	100	0	0
Korea	naver	100	0	0	75	100	25	0	0	0	0	0	0	100	0	0
Korea	nate	100	0	0	75	75	50	0	0	0	0	0	0	100	0	0
UAE	Arabo	100	0	0	50	75	75	0	0	0	0	0	0	100	0	0
Czech	seznam	100	0	0	100	0	100	0	0	0	0	0	0	100	0	0
Portugal	clix	100	0	0	100	0	75	0	0	0	0	0	0	100	0	0
Portugal	sapo	100	0	0	100	0	0	0	0	0	0	0	0	100	0	0
Japan	goo	100	0	0	75	75	0	0	0	0	0	0	0	100	0	0
Japan	excite	100	0	0	75	75	0	0	0	0	0	0	0	100	0	0
Cyprus	1stcyprus	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Germany	fireball	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Germany	bellnet	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Germany	Acoon	100	0	0	25	0	0	0	0	0	0	0	0	100	0	0
Germany	lycos	100	0	0	100	0	0	0	0	0	0	0	0	100	0	0
Germany	slider	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Germany	wlw	100	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Germany	suche	100	0	0	75	0	0	0	0	0	0	0	0	100	0	0

Table 12.6 Results of 20 children IQ Test

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Human	6Ages	100	100	100	25	0	25	50	50	50	75	50	25	100	100	100
Human	12Ages	100	100	100	25	25	75	75	75	100	100	100	75	100	100	100
human	18Ages	100	100	100	75	50	100	100	100	100	100	100	100	100	100	100

Table 12.7 Absolute IQ/relative IQ scores

				Absolute IQ	Relative IQ scores	K = 3	K = 4	K = 5
1		Human	18Ages	97	104.85	b	d	e
2		Human	12Ages	84.5	104.11	b	d	e
3		Human	6Ages	55.5	102.39	b	d	e
4	America	USA	google	26.5	102.13	b	a	a
5	Asia	China	Baidu	23.5	101.69	a	a	a
6	Asia	China	so	23.5	101.69	b	a	a
7	Asia	China	Sogou	22	101.41	a	a	a
8	Africa	Egypt	yell	20.5	100.32	b	a	a
9	Europe	Russia	Yandex	19	100.23	a	c	d
10	Europe	Russia	ramber	18	100.17	a	c	d
11	Europe	Spain	His	18	100.17	a	a	b
12	Europe	Czech	seznam	18	100.17	a	a	b
13	Europe	Portugal	clix	16.5	100.08	a	a	b
14	Asia	Korea	nate	15.75	100.03	a	c	d
15	Asia	UAE	Arabo	15.75	100.03	a	c	d
16	Asia	China	panguso	15	99.99	a	a	b
17	Asia	Korea	naver	15	99.99	a	c	d
18	Europe	Russia	webalta	13.5	99.9	a	c	d
19	America	USA	yahoo	13.5	99.9	a	c	d
20	America	USA	bing	13.5	99.9	a	c	d

(continued)

Table 12.7 (continued)

				Absolute IQ	Relative IQ scores	K = 3	K = 4	K = 5
21	Asia	Hong Kong	timway	12.75	99.86	a	a	b
22	Asia	Japan	goo	12.75	99.86	a	c	d
23	Asia	Japan	excite	12.75	99.86	a	c	d
24	Asia	China	Zhongsou	12	99.81	a	a	b
25	Europe	Britain	ask	12	99.81	a	c	d
26	Europe	France	voila	12	99.81	a	c	d
27	Europe	France	ycos	12	99.81	a	a	b
28	Europe	Portugal	sapo	12	99.81	a	a	b
29	Europe	Germany	lycos	12	99.81	a	a	b
30	Asia	India	khoj	10.5	99.72	a	a	b
31	Europe	Russia	Km	10.5	99.72	a	a	b
32	Europe	Germany	suche	10.5	99.72	a	a	b
33	America	USA	Dogpile	9	99.63	c	b	c
34	Europe	Germany	Acoon	7.5	99.55	c	b	c
35	Asia	Malaysia	Sajasearch	6	99.46	c	b	c
36	Asia	India	indiabook	6	99.46	c	b	c
37	Asia	Cyprus	1stcyprus	6	99.46	c	b	c
38	Europe	Greece	Gogreece	6	99.46	c	b	c
39	Europe	Holland	slider	6	99.46	c	b	c
40	Europe	Norway	Sunsteam	6	99.46	c	b	c
41	Europe	Britain	Excite UK	6	99.46	c	b	c
42	Europe	Britain	splut	6	99.46	c	b	C
43	Europe	Russia	Rol	6	99.46	c	b	C
44	Europe	Spain	ciao	6	99.46	c	b	C
45	Europe	Germany	fireball	6	99.46	c	b	C

46	Europe	Germany	bellnet	6	99.46	c	b	C
47	Europe	Germany	slider	6	99.46	c	b	C
48	Europe	Germany	wlw	6	99.46	c	b	C
49	Africa	Egypt	netegypt	6	99.46	c	b	C
50	Oceania	Solomons	eMaxia	6	99.46	c	b	C
51	Oceania	Australia	Anzswers	6	99.46	c	b	C
52	Oceania	Australia	Pictu	6	99.46	c	b	C
53	Oceania	New Zealand	SerachNZ	6	99.46	c	b	C

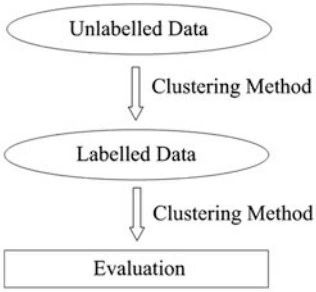


Fig. 12.1 Outline of clustering result evaluation

Table 12.8 In-sample result in original data

Algorithms	NB	DT (J48)	LR	KNN (K = 2)	SVM (SVM Linear)	NN (3 hidden layers)
Accuracy	100%	97.92%	100%	100%	100%	97.92%

algorithms are employed to evaluate and utilize the clustering results. The outline of this idea can be expressed in Fig. 12.1. Firstly, according to the IQ score and the result of K = 3, there are some intersections between group "a" and "b". As a result, for simplicity, it groups "a" and "b" as the same class, which can be labeled as +1. Then, the search engines corresponding to group c are labeled as −1. Then, it becomes a typical binary classification problem.

12.1.2.2 In-Sample Experiment

The result obtaining from the clustering can be evaluated as follows. One can know that a distinctly distinguishing classification problem will result in a high accuracy by using typical classification algorithms, such as Naïve Bayes (NB), Decision Tree (DT), Logistic Regression (LR), K Nearest Neighbor (KNN), Support Vector Machine (SVM) and Neural Network (NN). In other words, high accuracy results of these typical classification algorithms will indirectly and partially guarantee the high degree distinctness of clustering result. Based on this kind of thinking, we test our data in these 5 stable methods. The results can be found in Table 12.8. Here, fivefold cross validation is chosen to make the result more reliable and reasonable.

In Table 12.8, in-sample accuracies in various algorithms are all very high, which means we can partially depend on the clustering result and do prediction based on this result.

12.1.2.3 Out-Sample Experiment

This part shows the ability of generalization of the method. It finishes the IQ test on other 31 engines as new dataset. Furthermore, according to the clustering result on

Table 12.9 Out-sample result in original data

Algorithms	NB	DT (J48)	LR	KNN (K = 2)	SVM (SVM Linear)	NN (3 hidden layers)
Accuracy	90.32%	83.87%	83.87%	93.55%	77.42%	83.87%

original data, we arrange new data into three different clusters by Euclidean distance based on IQ test result. Then, taking these 31 engines as validation set, the original dataset containing 48 points as training set, we show the validation accuracies of various kinds of classification algorithms. According to the validation result in Table 12.9, the overall prediction accuracy is acceptable, which means the generalization of our method is reasonable and reliable.

12.1.3 A Standard Intelligence Model

This subsection proposes a standard intelligence model that unifies AI and human characteristics in terms of four aspects of knowledge, i.e., input, output, mastery, and creation. The model is established based on the theories of the von Neumann architecture, David Wechsler's human intelligence model, knowledge management using data, information, knowledge and wisdom (DIKW), and other related approaches.

The von Neumann architecture provided the inspiration that a standard intelligence system model should include an input/output (I/O) system that can obtain information from the outside world and feed results generated internally back to the outside world. In this way, the standard intelligence system can become a "live" system [11].

David Wechsler's definition of human intelligence led us to conceptualize intellectual ability as consisting of multiple factors; this is in opposition to the standard Turing test or visual Turing test paradigms, which only consider singular aspects of intellectual ability [12].

The DIKW model further led us to categorize wisdom as the ability to solve problems and accumulate knowledge, i.e., structured data and information obtained through constant interactions with the outside world. An intelligent system would not only master knowledge, it would have the innovative ability to be able to solve problems [13]. The ideas of knowledge mastery ability, being able to innovatively solve problems, David Wechsler's theory, and the von Neumann architecture can be combined, therefore we proposed a multilevel structure of the intellectual ability of an intelligent system–a "standard intelligence model," as shown in Fig. 12.2 [14].

In the basis of this research, the following criteria for defining a standard intelligence system are discussed. If a system (either an artificially intelligent system or a living system such as a human) has the following characteristics, it can be defined as a standard intelligence system:

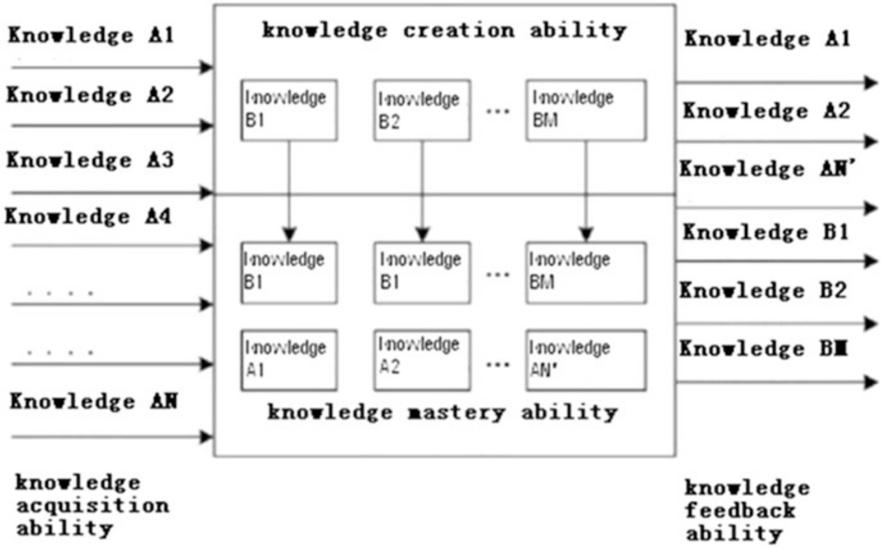


Fig. 12.2 The standard intelligence model

Characteristic 12.1 the system has the ability to obtain data, information, and knowledge from the outside world from aural, image, and/or textual input (such knowledge transfer includes, but is not limited to, these three modes);

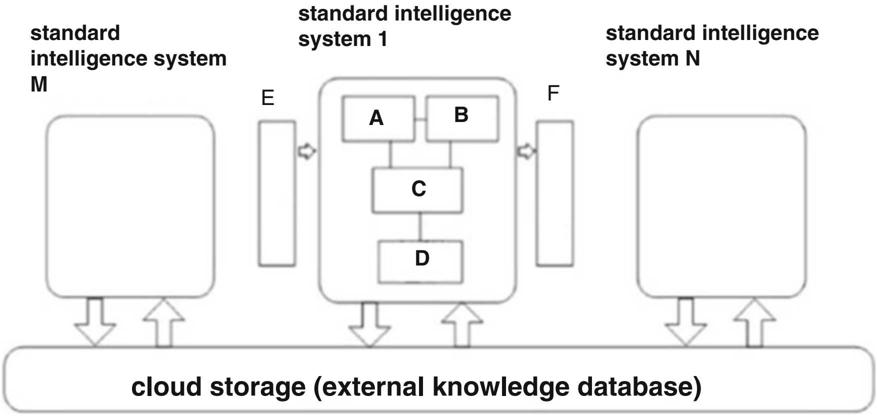
Characteristic 12.2 the system has the ability to transform such external data, information, and knowledge into internal knowledge that the system can master;

Characteristic 12.3 based on demand generated by external data, information, and knowledge, the system has the ability to use its own knowledge in an innovative manner. This innovative ability includes, but is not limited to, the ability to associate, create, imagine, discover, etc. New knowledge can be formed and obtained by the system through the use of this ability;

Characteristic 12.4 the system has the ability to feed data, information, and knowledge produced by the system feedback the outside world through aural, image, or textual output (in ways that include, but are not limited to, these three modes), allowing the system to amend the outside world.

12.1.3.1 Extensions of the von Neumann Architecture

The von Neumann architecture is an important reference point in the establishment of the standard intelligence model. Von Neumann architecture has five components: an arithmetic logic unit, a control unit, a memory unit, an input unit, and an output unit. By adding two new components to this architecture (compare Figs. 12.2 and 12.3), it is possible to express human, machine, and artificial intelligence systems in a more explicit way.



A. arithmetic logic unit
B. control unit
C. internal memory unit
D. innovation generator
E. input device
F. output device

Fig. 12.3 Expanded von Neumann architecture

The first added component is an innovative and creative function, which can find new knowledge elements and rules through the study of existing knowledge and save these into a memory used by the computer, controller, and I/O system. Based on this, the I/O can interact and exchange knowledge with the outside world. The second additional component is an external knowledge database or cloud storage that can carry out knowledge sharing. This represents an expansion of the external storage of the traditional von Neumann architecture, which is only for single systems (see Fig. 12.3).

Definition 12.5 A unified model of intelligent systems has four major characteristics, namely, the abilities to acquire, master, create, and feedback knowledge. The evaluation of the intelligence and developmental level of an intelligent system can be done by testing these four characteristics simultaneously.

The IQ of an artificial intelligence (AI-IQ) is based on a scaling and testing method defined according to the standard intelligence model. Such tests evaluate intelligence development levels, or grades, of intelligent systems at the time of testing, with the results delineating the AI IQ of the system at testing time [1].

Definition 12.6 A mathematical formula for AI IQ is given as:

$$Level1 : M \xrightarrow{f} Q, \quad Q = f(M) \tag{12.4}$$

Here, M represents an intelligent system, Q is the IQ of the intelligent system, and f is a function of the IQ.

Table 12.10 Ranking of top 13 artificial intelligence IQs in 2014

				Absolute IQ
1		Human	18 years old	97
2		Human	12 years old	84.5
3		Human	6 years old	55.5
4	America	America	Google	26.5
5	Asia	China	Baidu	23.5
6	Asia	China	so	23.5
7	Asia	China	Sogou	22
8	Africa	Egypt	yell	20.5
9	Europe	Russia	Yandex	19
10	Europe	Russia	ramber	18
11	Europe	Spain	His	18
12	Europe	Czech	seznam	18
13	Europe	Portugal	clix	16.5

In general, an intelligent system M should have four kinds of ability: knowledge acquisition (information acceptance ability), which we denote as I; knowledge output ability, or O; knowledge mastery and storage ability, S; and knowledge creation ability, C. The AI IQ of a system is determined based upon a comprehensive evaluation of these four types of ability. As these four ability parameters can have different weights, a linear decomposition of IQ function can be expressed as follows:

$$Q = f(M) = f\,(I, O, S, C) = a * f(I) + b * f(O) + c * f(S) + d * f(C)$$
$$a + b + c + d = 100\% \tag{12.5}$$

Based on this unified model of intelligent systems, an artificial intelligence IQ evaluation system can be established in 2014. By considering the four major ability types, 15 sub-tests were carried out and an artificial intelligence scale is formed. This scale is used to set up relevant question databases, tested 50 search engines and humans from three different age groups, and formed a ranking list of the AI IQs for that year [1] (see Sect. 12.2). Table 12.10 shows the top 13 AI IQs.

In 2016, the update AI-IQ tests for artificially intelligent systems was conducted again in evaluating the artificial intelligence systems of Google, Baidu, Sogou, and others as well as Apple's Siri and Microsoft's Xiaobing. The results indicate that the artificial intelligence systems produced by Google, Baidu, and others have significantly improved over the past 2 years but still have certain gaps as compared with even a 6-year-old child (see Table 12.11).

IQ essentially is a measurement of the ability and efficiency of intelligent systems in terms of knowledge mastery, learning, use, and creation. Therefore, IQ can be represented by different knowledge grades:

Table 12.11 IQ scores of artificial intelligence systems in 2016

				Absolute IQ
1	2014	Human	18 years old	97
2	2014	Human	12 years old	84.5
3	2014	Human	6 years old	55.5
4	America	America	Google	47.28
5	Asia	China	duer	37.2
6	Asia	China	Baidu	32.92
7	Asia	China	Sogou	32.25
8	America	America	Bing	31.98
9	America	America	Microsoft's Xiaobing	24.48
10	America	America	SIRI	23.94

Definition 12.7 A model of intelligence grade of artificial intelligence is given below:

$$\begin{aligned} &Level2 : Q \xrightarrow{\chi} K, K \in \{0, 1, 2, 3, 4, 5, 6\} \\ &K = \chi(Q) = \chi\,(f(M)) \end{aligned} \tag{12.6}$$

There are different intelligence and knowledge grades in human society. For instance, grades in the educational system such as undergraduate, master, doctor, as well as assistant researcher, associate professor, and professor. People within a given grade can differ in terms of their abilities; however, moving to a higher grade generally involves passing tests in order to demonstrate that watershed levels of knowledge, ability, qualifications, etc., have been surpassed.

How can key differences among the functions of intelligent systems be defined? The "standard intelligence model" (i.e., the expanded von Neumann architecture) can be used to inspire the following criteria:

– Can the system exchange information with (human) testers? Namely, does it have an I/O system?
– Is there an internal knowledge database in the system to store information and knowledge?
– Can the knowledge database update and expand?
– Can the knowledge database share knowledge with other artificial intelligence systems?
– In addition to learning from the outside world and updating its own knowledge database, can the system take the initiative to produce new knowledge and share this knowledge with other artificial intelligence systems?

Using the above criteria, a seven intelligence grades is presented by using mathematical formalism (see Table 12.12) to describe the intelligence quotient, Q, and the intelligence grade state, K, where K = {0, 1, 2, 3, 4, 5, 6}.

The different grades of K are described in Table 12.12 as follows.

The detailed explanation for the meaning of seven levels can be found in [2].

Table 12.12 Intelligence grades of intelligent systems

Intelligence grade	Mathematical conditions
0	Case 1, f(I) > 0, f(o) = 0; Case 2, f(I) = 0, f(o) > 0
1	f(I) = 0, f(o) = 0
2.	f(I) > 0, f(o) > 0, f(S)=α > 0, f(C) = 0; where α is a fixed value, and system M's knowledge cannot be shared by other M.
3	f(I) > 0, f(o) > 0,f(S) = α > 0, f(C) = 0; Where α increases with time.
4	f(I) > 0, f(o) > 0, f(S) = α > 0, f(C) = 0; where α increases with time, and M's knowledge can be shared by other M.
5	f(I) > 0, f(o) > 0, f(S) = α > 0, f(C) > 0; where α increases with time, and M's knowledge can be shared by other M.
6	f(I) > 0 and approaches infinity, f(o) > 0 and approaches infinity, f(S) > 0 and approaches infinity, f(C) > 0 and approaches infinity.

The research in the line of AI-IQ has some important implementations. For example, Fig. 12.4 shows a possible relationship between AI and Human intelligence. Here curve B indicates a gradual increase in human intelligence over time. There are two possible developments in artificial intelligence: curve A shows a rapid increase in the AI IQ, which is above the human IQ at a certain point in time. Curve C indicates that the AI IQ will be infinitely close to the human IQ but cannot exceed it. By conducting tests of the AI IQ, we can continue to analyze and determine the curve that shows a better evolution path of the AI IQ.

12.2 Laws of Intelligence Based on AI IQ Research

The subsection provides three laws of intelligence for interpreting the concepts of intelligence, wisdom, consciousness, life and non-life. The first law is called "M Law of Intelligence". The second law is called "*Ω* Law of Intelligence". The third law is called "A Law of Intelligence". The Three Laws need to be validated by a biochemical experiment method, an AI system intelligence evaluation experiment method or the computer program simulation experiment method.

To illustrate the laws, the following symbol stipulation on related concepts are used:

Symbol 1*: U stands for the entire Universe*

Symbol 2*: a stands for an individual Agent, and A for the set of all individual Agents in Universe, $a \in A$*

Symbol 3*: E_a stands for the environment that affects the survival of Agent a, that is, the entire environment that can interact with Agent a.*

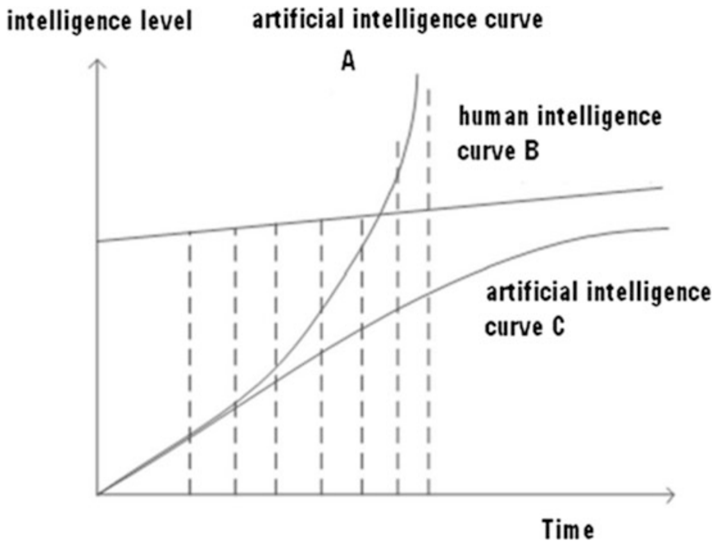


Fig. 12.4 Developmental curves of artificial and human intelligence

Symbol 4: *K(X) stands for the set of knowledge that can be processed or contained by X. For example, K(a) stands for a set of knowledge that can be processed or contained by Agent a; K(U) stands for all sets of knowledge that can be processed or contained by Universe, and* $K(E_a)$ *stands for all sets of knowledge that can be processed or contained by the environment where Agent a exists.*

12.2.1 Law of Intelligent Model (M Law)

The first law of intelligence is called Law of Intelligent Model, namely M Law. The goal of this law is to establish a unified model, used to describe the key features of any Agent, and it is detailed as follows:

Definition 12.8 Any Agent can be regarded as a system with abilities to input, output, storage(master), creative(innovate) knowledge, and the difference between Agents is that different Agents have different abilities to process knowledge with these four functions.

The quaternary mathematical expression of **Law of Intelligent Model** is:

$$a = (I_a, O_a, S_a, C_a) \quad (12.7)$$

In this mathematical description, $a \in A$ stands for any Agent.

K stands for a knowledge set.

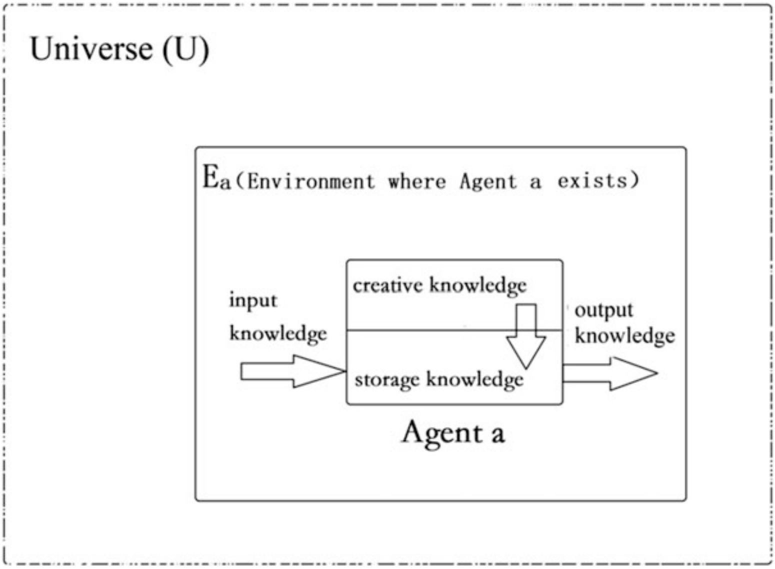


Fig. 12.5 Schematic diagram of the M Law of Intelligence

I_a stands for the ability of Agent a to input knowledge from its environment (E_a).

O_a stands for the ability of Agent a to output knowledge, and the result is the effect on its environment (E_a) (including other Agents).

S_a stands for the ability of Agent a to translate the input knowledge and its own innovative knowledge into storage or mastery of knowledge.

C_a stands for the ability of Agent a to creative or innovate knowledge based on the input and mastery of knowledge.

The four abilities of Agents to process knowledge are respectively between 0 and infinity. The set $K(a)$ of knowledge that any Agent can process is the union of the knowledge sets that the above four abilities can process. Its mathematical expression is: $0 \leq |K(I_a)|, |K(O_a)|, |K(S_a)|, |K(C_a)| \leq \infty$, $K(a) = K(I_a) \cup K(O_a) \cup K(S_a) \cup K(C_a)$.

The illustration of M Law of Intelligence is shown in Fig. 12.5.

According to the M Law of Intelligence, the definitions of the following five concepts may be proposed, which will play an important role in the proposal of subsequent laws.

12.2.2 Absolute 0 Agents (α_{point})

According to the mathematical description of Standard Intelligent Model, i.e. $a = (I_a, O_a, S_a, C_a)$, it can be seen that when the input, output, storage(mastery) and creative(innovation) abilities of an Agent equal to zero, a special state of the Agent

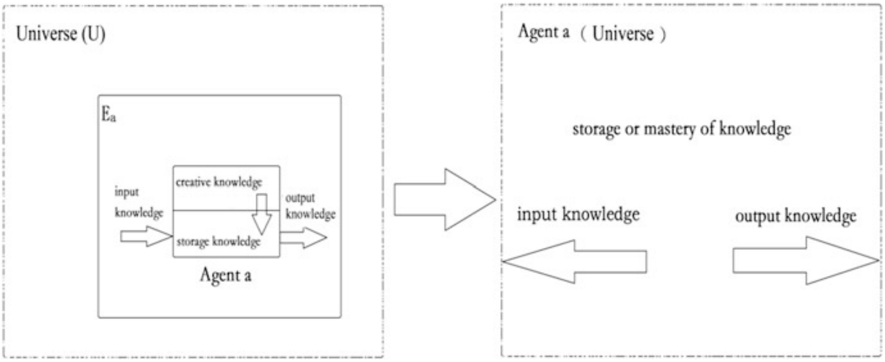


Fig. 12.6 Schematic diagram of the formation of omniscient and omnipotent agent

will form, which is the reason for the proposal of the absolute 0 Agent (α_{point}). It notes the final boundary of Agent's ability to change to infinitesimal.

Definition 12.9 $\exists a \in A$, $|K(I_a)| = 0$, $|K(O_a)| = 0$, $|K(S_a)| = 0$ and $|K(C_a)| = 0$, a is an absolute 0 Agent, denoted as α_{point}, and the set they form is denoted as A_{POINT}.

12.2.3 Omniscient and Omnipotent Agents (Ω_{point})

As discussed above, when the Agent's ability to process knowledge converges to the "0" state, the Agent will become an absolute 0 Agent. Similarly, for Agent a, when its abilities to input, output, storage(master) and creative(innovate) knowledge equal to infinity, another special state will form, which is why the Omniscient and Omnipotent Agent is proposed. The proposal of Omniscient and Omnipotent Agent presents the final boundary of the Agent's ability to change to infinity.

There will be a special situation in the process that Agent a forms an Omniscient and Omnipotent Agent. Specifically, while Agent a's abilities to innovate, input, output and master knowledge are approaching infinity, once the ability to master knowledge equals to infinity, the innovation ability is sure to be zero, otherwise, It will be paradoxical relative to the fact that Agent a's ability to master knowledge is infinite, as shown in Fig. 12.6.

At the same time, because for Agent a, there should be no "external" concept, so for Agent a, both input and output will occur inside it, as shown in Fig. 12.6. Basis on the above, it can be concluded that if there is an Omniscient and Omnipotent Agent, there can only be one. It is mathematically described as follows:

Definition 12.10 $\exists a \in A$, $|K(I_a)| = \infty$, $|K(O_a)| = \infty$ and $|K(S_a)| = \infty$, $|K(C_a)| = 0$, a is an Omniscient and Omnipotent Agent, denoted as Ω_{point}, there can only be one Ω_{point}.

12.2.4 Conventional Agent (a_C)

Given Agent a, it is neither an absolute 0 Agent, nor an Omniscient and Omnipotent Agent, that is, its ability to process knowledge is between 0 and infinity, then a is a conventional Agent, mathematically described as follows:

Definition 12.11 $\exists a \in A$, $0 < |K(I_a)| < \infty$, $0 < |K(C_a)| < \infty$, $0 < |K(O_a)| < \infty$ and $0 < |K(S_a)| < \infty$, a is a conventional Agent, denoted as a_C. The set formed by conventional Agents is denoted as A_C.

12.2.5 Relative 0 Agent (a_R)

For any two conventional Agents, if there is no intersection between the sets formed by the knowledge processed by them, then they are mutually relative *0* Agents, mathematically described as follows:

Definition 12.12 $\exists a_i$, $a_{i+1} \in A_N$, $K(a_i) \cap K(a_{i+1}) = \emptyset$, a_i and a_{i+1} are mutually relative 0 Agents, denoted as a_R, i.e. a_i is the a_R of a_{i+1}, similarly, a_{i+1} is the a_R of a_i. The relative 0 Agent set of an Agent is denoted as A_R.

The existence of relative 0 Agents indicates that even if two Agents are not absolute 0 Agents, they will also treat each other as an absolute 0 Agent as there is no way for them to exchange or share knowledge.

12.2.6 Shared Agent ($a_G$or A_G)

$a_1, a_2, a_3, \ldots a_J$ are all Agents. If at least one knowledge element k_i is same in the knowledge sets of these agents, then they constitute a shared Agent (set). According to the definition of Standard Intelligent Model, the shared Agent (set) can also be regarded as an Agent, mathematically described as follows:

Definition 12.13 $\exists a_1, a_2, a_3, \ldots a_J \in A$, $K(a_1) \cap K(a_2) \cap K(a_3) \ldots \cap K(a_J) \neq \emptyset$, the system formed by $a_1, a_2, a_3, \ldots a_J$ can be called a shared Agent. A shared Agent may be a set, denoted as A_G, or it may be an Agent, denoted as a_G.

The shared Agent is a larger intelligent system formed by different Agents through the sharing and exchange of knowledge. This will be of great significance and value to all the Agents that constitute the shared Agent, allowing an individual Agent to have stronger ability to process knowledge.

Specially, if all Agents in an Agents set are absolute *0* Agents, then these Agents form a special shared Agent, and we call it as Absolute *0* shared Agent, which is mathematically described as follows:

Definition 12.14 $\exists a_1, a_2, a_3, \ldots a_J \in A_{point}$, The system formed by $a_1, a_2, a_3, \ldots a_J$ can be called as Absolute 0 shared Agent, which is also an Absolute 0 Agent.

12.2.7 Universe Agent (a_U)

We observe that:

1. If an agent a evolves into Omniscient and Omnipotent Agent, by definition, this agent will expand to the entire universe at this time, that is, the universe can be regarded as Omniscient and Omnipotent Agent at this time;
2. If all agents in the universe are Absolute *0* agents, the universe can be regarded as Absolute *0* agent according to the definition of Absolute *0* agents and Absolute *0* shared agent;
3. If all the agents included in Universe are Absolute *0* Agents and Conventional Agents, or all are Conventional Agents, then Universe can be regarded as a special kind of Conventional Agent.

Therefore, Universe can be regarded as an Agent that can change in states such as Absolute *0* agent, Conventional Agent and Omniscient and Omnipotent Agent. In this section, it is named Universe agent ($\boldsymbol{a_U}$).

Definition 12.15 Because

1. $\exists a \in A$, $a = \Omega point \Rightarrow U = \Omega_{point}$,
2. $\forall a \in A$, $a \in Apoint \Rightarrow U = \alpha_{point}$,
3. $\exists a \in A$, $a \in A_C \Rightarrow U = a_C$,

we have that U∈A, U is Agent, noted as a_U.

12.2.8 Law of Intelligence Evolution (Ω Law)

The second law of intelligence is called Law of Intelligence Evolution, namely Ω Law. This law interprets the evolution of a Agent to the Omniscient and Omnipotent Agent ($\boldsymbol{\Omega_{point}}$), with the content as follows:

Definition 12.16 Any Agent will evolve directly or indirectly toward the Omniscient and Omnipotent Agent (Ω_{point}) under the effect of F_Ω (*Ω gravity*). In the process of evolution, it is also directly or indirectly subject to F_α (*α gravity*) which hinders the Agent's speed to evolve toward Ω_{point}, especially when F_α (*α gravity*) is constantly greater than F_{Ω} (Ω *gravity*), the Agent will converge toward the absolute 0 Agent (α_{point}).

The mathematical expression of **Law of Intelligence Evolution** is:

$$(0, 0, 0, 0) \overset{F_A}{\leftarrow} (I_a, O_a, S_a, C_a) \overset{F_{\Omega}}{\rightarrow} (\infty, \infty, \infty, 0)$$

or

$$\alpha_{\text{point}} \overset{\text{F}_{\text{A}}}{\leftarrow} a \overset{\text{F}_{\Omega}}{\rightarrow} \Omega_{\text{point}}$$

The law is related to the existence of two special states of the Intelligent Model. As seen from Definitions 12.9–12.10, there are Omniscient and Omnipotent Agents (Ω_{point}) and absolute 0 Agents (α_{point}).

When the Agent changes toward these two states, two "forces" are theoretically required to drive the Agent to evolve toward Ω_{point} or converge toward α_{point}. Therefore, we call the "force" driving the Agent to evolve toward Ω_{point} as F_{Ω} (Ω *gravity*), the "force" driving the Agent to converge toward α_{point} as F_{α} (α *gravity*). The changes of the Agent towards Ω_{point} or α_{point} are shown in Fig. 12.7.

As viewed from the hundreds of millions of years of history in biological evolution, it may be noted that the signs of effects of Ω Law on biological populations can be seen from changes in the ability of different populations to process knowledge.

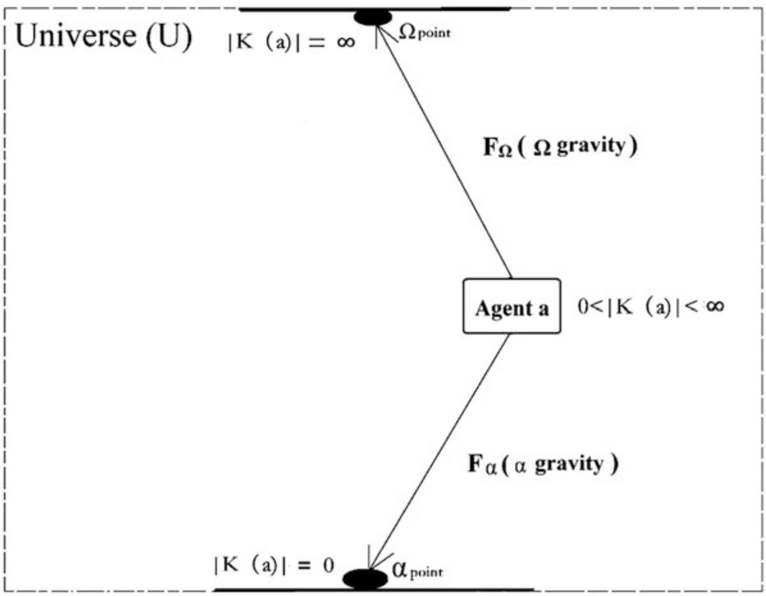


Fig. 12.7 Schematic diagram of Law of Intelligence Evolution

Although different organisms show the biodiversity. As examples, sharks, dinosaurs, pandas and the human can be discussed further as below.

Although there are no precise statistics, according to the common sense, we know that sharks have little change in the new knowledge they have mastered, and the biological population of sharks's ability to process knowledge has changed little during the hundreds of millions of years they have survived [15]. Pandas are on the verge of extinction because of their own and environmental reasons, and the biological population of Pandas's ability to process knowledge is shrinking. Dinosaurs failed to withstand natural disasters 65 million years ago and the entire biological population went extinct [16]. This is equivalent to that dinosaurs converged to an Absolute *0* Agent (α_{point}) under the effect of F_α (*α gravity*), no matter whether they were in the form of a population or individuals. For the human, the biological population's ability to process knowledge has grown considerably since 200,000 years ago when it mastered the use of language [17]. Especially during the recent hundreds of years, with the outbreak of the industrial revolution, the development of physics, and the birth of the Internet, the human's abilities to master knowledge and transform the world has experienced the accelerated growth.

Suppose there is no unfavorable situation such as major disasters, it can be deduced from this trend that the biological population represented by the human will reach the "Omniscient and Omnipotent Agent (Ω_{point})" state when the time approaches the infinite time point. The historical changes in the knowledge processing abilities of sharks, pandas, dinosaurs and the human may be illustrated on the same diagram for comparison [18], as shown in Fig. 12.8. Based on the Ω Law of Intelligence, the following six definitions may be proposed:

12.2.8.1 F_Ω(Ω*gravity*)

In the second law, i.e., Ω law, a "force" is inevitably required as a drive so that Agent a reaches Omniscience and Omnipotence state (Ω_{point}). Such a theoretical demand is the first reason for the proposal of F_Ω (*Ω gravity*).

Meanwhile, if observing the development law of population knowledge bases of the human, sharks, pandas, dinosaurs, etc., we can also find signs of the effects of F_Ω (*Ω gravity*). From this, we can propose the definition of F_Ω (*Ω gravity*) as below:

Definition 12.17 F_Ω (*Ω gravity*) is an "force" directly or indirectly acting upon any Agent, and the result of such action is that Agent or Shared Agent (a_G) in which the Agent is involved approaches toward the Ω_{point} state, namely, the abilities of Agent or Shared Agent (a_G) in the input, output, storage(master) and creative(innovate) of knowledge continuously grow and eventually reach Ω_{point}.

Although the specific principles and effects of F_Ω (*Ω* gravity) are still unknown to us so far, a quantitative research on how F_Ω (*Ω* gravity) acts upon agents may be conducted with a biochemical experiment method, an AI system intelligence evaluation experiment method or a computer program simulation experiment method.

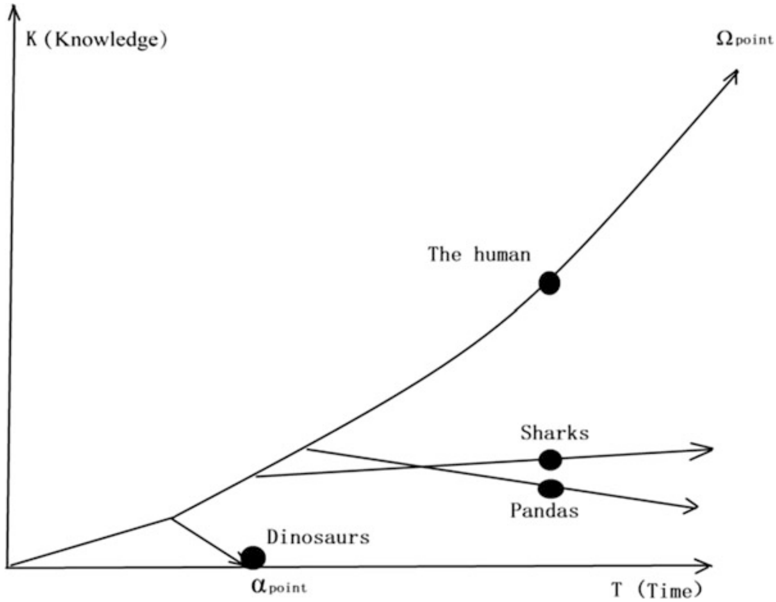


Fig. 12.8 Schematic diagram for the development of biological population's ability to process knowledge

We can also try summarizing the calculation formula of F_{Ω} (Ω gravitational force) on this basis.

12.2.8.2 $F_{alpha}(\alpha gravity)$

Similarly, an influencing factor is also inevitably required so that the Agent converges toward the absolute 0 Agent (α_{point}). Such a theoretical demand is the first reason for the proposal of $\boldsymbol{F}_{\alpha}$ (α *gravity*).

In nature, there are phenomena of aging, fading and death of biological populations, biological individuals or artificial intelligence systems, which correspond to the situation that the Agent converges toward the Absolute *0* Agent (α_{point}). From this, we propose the following definition of $\boldsymbol{F}_{\alpha}$ (α *gravity*):

Definition 12.18 $\boldsymbol{F}_{\alpha}$ (α *gravity*) is an "force" directly or indirectly acting upon any Agent, and the result of such action is that Agent's abilities to input, output, storage(master) and creative(innovate) knowledge continuously decline, and eventually converge to α_{point}.

Similarly, the research on $\boldsymbol{F}_{\alpha}$ (α *gravity*) remains to be explored at this day. It should be combined with the research of F_{Ω} (Ω *gravity*) in the future. Thereby, we can conduct the quantitative research on how $\boldsymbol{F}_{\alpha}$ (α *gravity*) acts upon agents by using the three methods mentioned above and try to summarize the calculation formula of $\boldsymbol{F}_{\alpha}$ (α *gravity*).

12.2.8.3 Agent of Life and Agent of Engineering (a_L*and* a_E)

As the main parts for the generation of intelligence, life and artificial intelligence have always been in dispute in terms of their definitions. What is life? Schrodinger, a physicist, proposed in his book with the title of *What Is Life* that *the characteristic of life is that life can constantly obtain "negative entropy" from the surrounding environment to counter the inevitable increase of entropy in life activities* [19]. Then, what is artificial intelligence? Winston believes that *artificial intelligence is a science about how to make computers do intelligent work that could only be done by the human in the past* [20]. Corresponding to life and artificial intelligence, life agent and engineering agent are proposed in this section, and they are also deduced and defined as follows according to the second law of intelligence.

In the definition of F_{Ω} (Ω *gravity*), we mentioned that F_{Ω} (Ω gravity) directly or indirectly acts upon the Agent. Therefore, we identify an Agent according to whether it is directly subject to F_{Ω} (Ω *gravity*). Then, the definitions of life Agents and engineering Agents are proposed as follows:

Definition 12.19 Among all Agents (A set) in Universe, those Agents that are directly driven by F_{Ω} (Ω *gravity*) are called Agent of Life (a_L).

Definition 12.20 Among all Agents (A set) in Universe, those Agents that are not directly driven by F_{Ω} (Ω *gravity*) are called Agent of Engineering (a_E).

From the existing examples in the real world, the Agents like the human, dinosaurs, sharks, pandas should belong to the category of Agent of life, while the robots, artificial intelligence programs and other systems invented by the human may be regarded as Agents of engineering.

The running power and rules of the Agent of engineering are derived from the Agent of Life or other Agents of engineering. From the purpose that the human create artificial intelligence systems, robots and AI programs still provide services for the continuous development of the human [21]. Therefore, it can be considered that Agents of engineering are indirectly affected by F_{Ω} (Ω *gravity)*, which assists Agents of life to develop towards Ω_{point}.

12.2.8.4 Intelligence

Intelligence is the core issue of our discussion. An important goal to put forward the three laws of intelligence is to answer the question of "*what is intelligence*". Currently, there are also many definitions or controversies about this question. For example, V.A.C. Henmon argues that *intelligence is the ability to acquire and retain* *knowledge* [22], while Alfred Binet defines intelligence as *the ability of reasoning, judging, memorizing, and abstracting* [23].

Seen from M Law and Ω Law of Intelligence, any Agent processes knowledge and interacts with the outside world through the input, output, mastery and innovation functions. Besides, F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*) are the key driving forces for the Agent to process knowledge. Therefore, we propose the following definitions of intelligence:

Definition 12.21 The ability of an Agent to apply knowledge through input, output, mastery and innovation functions under the direct or indirect effects of F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*) is called intelligence (capability); or the phenomenon that knowledge flows inside and outside the Agent through the input, output, mastery and innovation functions of the Agent under the joint action of F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*), is called intelligence (phenomenon).

12.2.8.5 Consciousness

Consciousness is a concept closely related to intelligence. Then, what is consciousness and what is the difference between consciousness and intelligence? These questions are also the focus of debate among researchers. The understanding of consciousness in psychology involves its broad definition and narrow definition. From the broad definition, consciousness refers to the brain's response to the objective world, while from the narrow definition, it refers to people's awareness and attention to the outside world and themselves [24].

Tulving proposed in his book with the title of *Memory and Consciousness* that *consciousness is the name given to the kind of consciousness that mediates an individual awareness of his or her existence and identity in subjective time extending from the personal past through the present to the personal future* [25].

In the definition of intelligence in this section, it is mentioned that some Agents (*Agent of life*) are intelligence generated under the direct action of F_Ω *(Ω gravity)* and $\boldsymbol{F}_\alpha$ (*α gravity*), and the remaining Agents (*Agent of engineering*) are the intelligence generated by the indirect action. Therefore, whether the Agent is directly affected by F_Ω *(Ω gravity)* and $\boldsymbol{F}_\alpha$ (*α gravity*), and whether it can perceive F_Ω *(Ω gravity)* and $\boldsymbol{F}_\alpha$ (*α gravity*) and form corresponding knowledge are used as a standard for defining consciousness. So that consciousness can be an important feature to distinguish Agents of life and Agents of engineering. Therefore, the consciousness is defined as follows:

Definition 12.22 When the Agent that is directly driven by F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*) achieves the application of knowledge through the knowledge input, output, mastery and innovation functions, it can perceive the effects of F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*), and thus contain the understanding on F_Ω (*Ω gravity*) and $\boldsymbol{F}_\alpha$ (*α gravity*) in the knowledge mastered by it, this ability or phenomenon is called consciousness.

12.2.8.6 Law of Intelligence (Zero-Infinity) Duality (A Law)

The third law of intelligence is called Law of Intelligence (*zero-infinity*) Duality, namely A Law, with the content that when an Agent changes around the "absolute 0 Agent" (α_{point}), Universe will have existence and inexistence phenomena for this Agent, or the amount of knowledge contained in Universe will also change between 0 and infinity relative to this Agent. It is elaborated as follows:

Definition 12.23 For any Agent, when it converges to α_{point}, the entire Universe (the amount of knowledge, including but not limited to information, concepts, data, laws, time, matter, space, etc.) will become an empty set or "0" state, or we say Universe will not exist relative to this Agent. On the other hand, when the Agent changes from α_{point} to a conventional Agent (a_C), the entire Universe (the amount of knowledge) (including but not limited to information, concepts, data, laws, time, matter, space, etc.) will become infinity. In short, relative to this Agent at this time, Universe exists and there is an infinite amount of knowledge in cognition that needs to be mastered.

The mathematical expression of Law of Intelligence (zero-infinity) Duality is:

$$a \in A_{point}, |K(U)| = 0; \quad a \notin A_{point}, |K(U)| = \infty$$

or

$$O \overset{a}{=\!=\!=\!=} \infty$$

In order to express this law succinctly, we replaced the formula $a{\in}Apoint, |K(U)| = 0$; $a{\notin}Apoint$, $|K(U)| = \infty$ with $O \overset{a}{=\!=\!=\!=} \infty$, which shows that relative to an Agent, Universe (amount of knowledge) will change between 0 (empty) and infinity due to the change of the Agent's state.

The meaning of the third law of intelligence is as shown in Fig. 12.9.

If the second law focuses on elaboration of the effects of Ω_{point} on the Agent and Universe, then the third law is to elaborate the effects of α_{point} on the Agent and Universe.

In the real world, there are a large number of cases that the Agent converges to the α_{point}. Such as the extinction of dinosaurs as a population, the natural death or accidental death of human individuals, and the complete scrap of computers or robots due to damage of parts. These phenomena can be regarded as the cases that the Agent converges to α_{point}.

What needs to be studied and thought is, when the Agent converges from a conventional Agent to α_{point}, does the entire Universe still exist relative to this Agent?

According to the definition of absolute *0* Agent (α_{point}), this Agent can neither perceive or output any knowledge, nor create new knowledge, nor master any knowledge. In this case, any element of Universe should be empty or non-existent relative to this Agent. In special cases, when all the Agents in Universe converge to

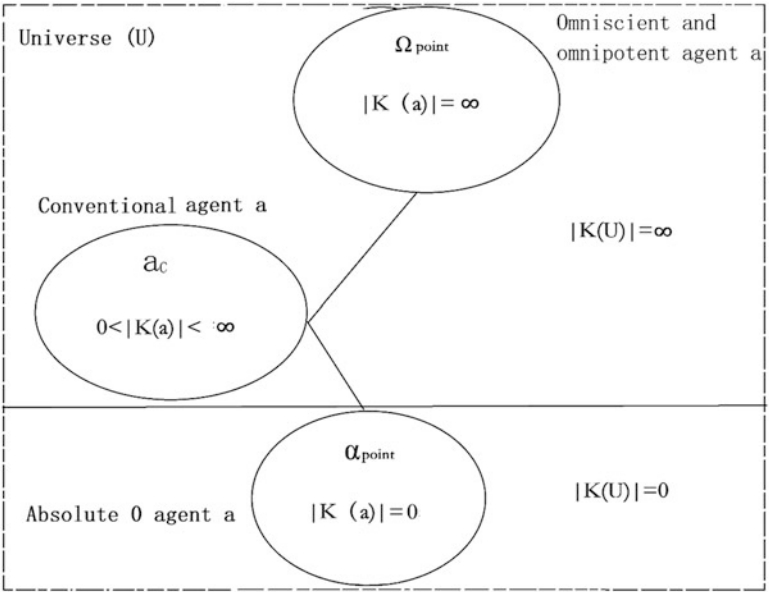


Fig. 12.9 Schematic diagram of Law of Intelligence (zero-infinity) Duality

absolute 0 Agents, the entire Universe will converge to the absolute 0 intelligence state. In the absolute 0 intelligence state, Universe will no longer contain any concepts, elements, knowledge, matter, time, space, or laws, and the entire Universe will be completely empty. When a Conventional Agent appears in Universe which is in Absolute 0 intelligence state, the knowledge contained in Universe (including but not limited to various concepts, elements, knowledge, matter, time, space, law, etc.) will exist relative to the born Conventional Agent or Universe at this time, and will continue to emerge with the evolution of the Agent. Then, how this knowledge emerges and what characteristics and laws involve will be further elaborated in future research.

The relationships between these three intelligence laws are shown in Fig. 12.10.

The further validation of the scientific value of the Three Laws remains to be explored. It can be carried out along two directions. The first direction is to conduct experiments in the real-world environment by means of the technologies and objects in the fields of biochemistry and AI systems. The second direction is to conduct experiments in virtual simulation programs, using the technologies like game dynamics, cellular automaton, AMB simulation.

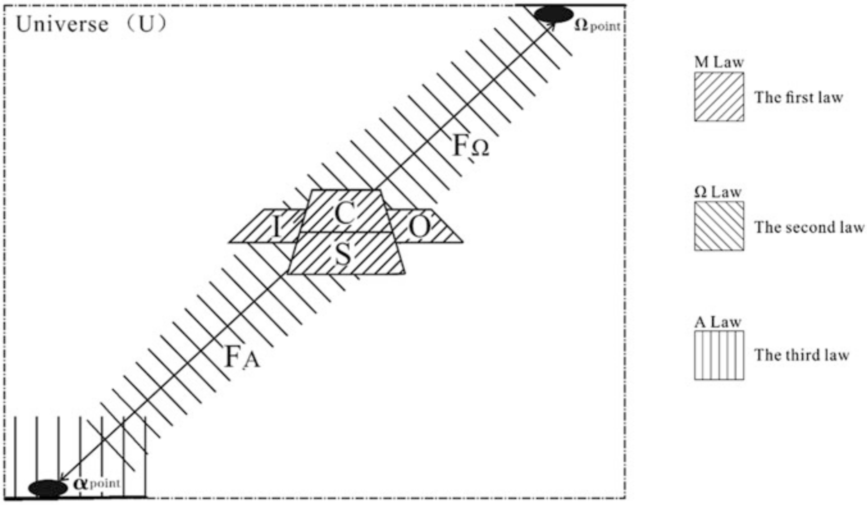


Fig. 12.10 Relationships between three intelligence laws

12.3 A Fuzzy Cognitive Map-Based Approach Finding Characteristics on AI-IQ Test

The determination of IQ test characteristics of Artificial Intelligence (AI) systems can vary depending a methodology is chosen. The subsection provides a Fuzzy Cognitive Map (FCM) approach to improve the IQ test characteristics of Artificial Intelligence (AI) systems. The defuzzification process makes use of fuzzy logic and the triangular membership function along with linguistic term analyses. Each edge of the proposed FCM is assigned to a positive or negative influence type associated with a quantitative weight. All the weights are based on the de-fuzzified value in the defuzzification results. It also leverages a dynamic scenario analysis to investigate the interrelationships between driver concepts and other concepts. Worst and best-case scenarios have been conducted on the correlation among concepts.

Based on the test bank of Sect. 12.1.2, like a human IQ test, each search engine needs to answer several questions that are selected from the developed test bank by random. For each question, they will receive a score between 0 and 100. This framework divides all the questions into four main indicator groups and further into 15 characteristics. Also, a few adult volunteers had the IQ test for the purpose of standardizing the IQ score, and mapping with the human being's IQ score.

Table 12.13 lists all the 15 IQ characteristics along with their corresponding weights for testing AI systems. After gathering expert opinions (Delphi method), all the 15 weights are calculated and presented in the Table 12.13. Where

C1m (m = 1,2 . . . m) = ability to acquire knowledge.
C2n (n = 1,2 . . . n) = ability to master knowledge.

Table 12.13 Fifteen IQ Characteristics for AI system and their corresponding Delphi weights

C1m	C2n	C3p	C4q
C11: Ability to identify word (3%)	C21: Ability to master general knowledge (6%)	C31: Ability to innovate by association (12%)	C41: Word feedback ability (3%)
C12: Ability to identify sound (3%)	C22: Ability to master translation (3%)	C32: Ability to innovate by creation (12%)	C42: Sound feedback ability (3%)
C13: Ability to identify image (4%)	C23: Ability to master calculation (6%)	C33: Ability to innovate by speculation (12%)	C43: Image feedback ability (4%)
	C24: Ability to master arrangement (5%)	C34: Ability to innovate by selection (12%)	
		C35: Ability to innovate by discover laws (12%)	

C3p (p = 1,2 . . . p) = ability to innovate knowledge.
C4q (q = 1,2 . . . q) = ability of knowledge feedback.

The proposed IQ test question bank is arranged according to all the 15 IQ characteristics (concepts). To illustrate, an example of testing question: "Please translate 'Technology's impact' into Spanish" should belong to characteristic C22 (Ability to master translation).

The results of Delphi weights are very subjective. Because they are coming from expert's own judgment, which means the results may be biased. Take advantage of linguistic terms from literature sources can be treated as a better method because all the literature publication sources are considered as an objective approach. One of the article's goals is to assign new weights though the fuzzy logic method (an objective approach). Based on the new weights, the interrelations among characteristics also should be investigated. There are some significant relationships among some characteristics. For example, "C21: Ability to master general knowledge" literally has a positive impact on "C24: Ability to master arrangement".

12.3.1 Research Method

12.3.1.1 Methodology

Fuzzy Cognitive Mapping (FCM) is the most important method of this research article. For the purpose of constructing FCM, the number of edges should be clarified. Theoretically, all the combination of two concepts should have an edge (relationship). However, the literature resources only support the meaningful edges, for example, the edge between one IQ characteristic and the AI system, or the edges of the interrelations among the 15 IQ characteristics. According to the literature resources, it is easy to assign the influence type (negative, positive, or null) of the edge. Keyword extraction plays a significant role in the relationship between concepts capturing. For instance, one reference paper said concept C22 heavily impacts concept C31, then, keyword “heavily impacts” will be extracted here. Each keyword will be assigned with one of the linguistic terms (“VERY LOW”, “LOW”, “MEDIUM”, “HIGH”, and “VERY HIGH”). At least three linguistic terms will be assigned to each edge.

The linguistic terms are fuzzy set problems. The membership function plays a significant role in quantifying the membership grade of the element in X to the fuzzy set.

$$\mu_{\mathrm{A}} : X \rightarrow [0, 1] \tag{12.8}$$

Where X represents the universe of discourse while the fuzzy set is A, and A is the membership function [26].

A triangular function will be used in the FCM constructing process. Where a is the lower limit, b is the upper limit, and m is a value between a and b. Figure 12.11 illustrates the membership function as a graph.

$$\mu_{\mathrm{A}} = \begin{cases} 0, x \leq a \\ \frac{x-a}{m-a}, a < x \leq m \\ \frac{b-x}{b-m}, m < x \leq b \\ 0, x > b \end{cases} \tag{12.9}$$

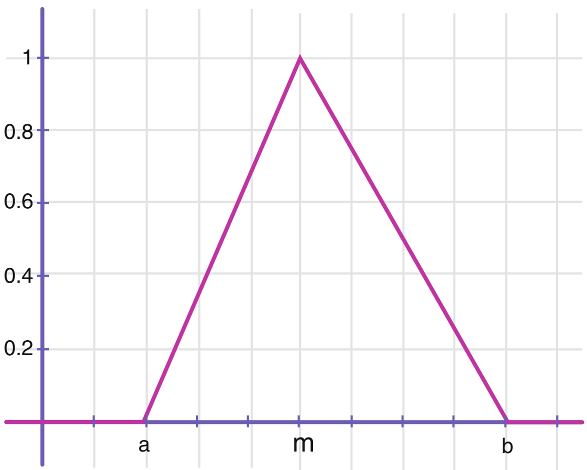


Fig. 12.11 Membership function graph [27]

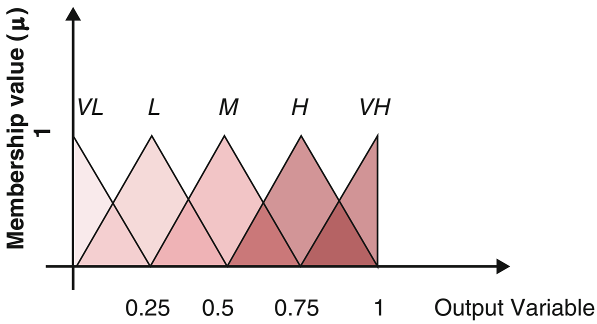


Fig. 12.12 Triangular membership function [59]

12.3.1.2 Linguistic Term Analyses

Table 12.14 summarizes all the possible relationships between each IQ characteristic and the AI system, and the interrelationship among the 15 IQ characteristics. In particular, Barwise's paper mentioned IQ characteristics' ability to identify word is a "most common view" of AI system [18]. Then, the keyword "most common view" will be extracted here, while a linguistic term "HIGH" will be assigned to this edge. Table 12.14 gives an outline of the linguistic terms, influence type, and keywords.

In Table 12.14, "C" represents the "AI system IQ".

Based on the extracted keyword results, Table 12.15 is a more advanced tabulation is used to summary keyword information into a table according to their linguistic terms.

12.3.1.3 Defuzzification Method

Tables 12.14 and 12.15 present a tabulation of the defined five linguistic terms in the fuzzy set we will use later. The Triangular Membership Function [59] which is shown in Fig. 12.12 means different linguistic terms have different output values.

For the purpose of converting a fuzzified output values into a traditional single crisp value, defuzzification process will be used here [60]. Among the existing defuzzification approaches (COG, COA, BOA, etc.), in this research article, we use the Center of Sums (COS) approach, which is one very useful approach for the defuzzification process [60, 61]. This equation of COS is below:

$$x^* = \frac{\sum_{i=1}^{N} x_i * \sum_{k=1}^{N} \mu A_K\,(x_i)}{\sum_{i=1}^{N} \sum_{k=1}^{n} \mu A_K\,(x_i)} \tag{12.10}$$

Table 12.14 Linguistic terms

Edge of FCM	Keyword	Linguistic term
C11-C	an aspect of	LOW
	an aspect of	LOW
	an aspect of	LOW
C12-C	a key strategic	HIGH
	core capabilities	HIGH
	obvious	LOW
C13-C	core capabilities	HIGH
	enable	MEDIUM
C21-C	important component	HIGH
	correlated	MEDIUM
	partly represented	LOW
	related to	MEDIUM
C22-C	no significant correlation	VERY LOW
	week relationship	LOW
	no interrelationship	VERY LOW
C23-C	intersection	LOW
	accelerate	MEDIUM
	interleave	MEDIUM
C24-C	a significant	MEDIUM
	common view	MEDIUM
C31-C	interpreted to	MEDIUM
	display	MEDIUM
	measures of	HIGH
C32-C	demonstrates	HIGH
	must entail	VERY HIGH
	referred to	HIGH
	been central to	VERY HIGH
	fundamental to	VERY HIGH
	can be important	HIGH
C34-C	directly	MEDIUM
	commonly used	MEDIUM
	connects to	MEDIUM
C35-C3	related to	MEDIUM
	may affect	LOW
C41-C	are as likely to	LOW
	important element	MEDIUM
	a key for	HIGH
C42-C	linked to	LOW
	taken into consideration	MEDIUM
	is important to	HIGH

(continued)

Table 12.14 (continued)

Edge of FCM	Keyword	Linguistic term
C43-C	dominated by	HIGH
	driven by	MEDIUM
	result in	HIGH
C11-C12	statistically significant	MEDIUM
	foundational	VERY HIGH
	strong connected	VERY HIGH
C11-C13	improve	MEDIUM
	dependent	MEDIUM
	benefit	MEDIUM
C21-C22	important	MEDIUM
	widely identified as	LOW
	never an empty mind of	MEDIUM
C21-C23	result from	HIGH
	partially predicted by	LOW
	as the basis	MEDIUM
C21-C24	commonly used	MEDIUM
	spontaneously	MEDIUM
	related to	MEDIUM
C21-C31	able to	MEDIUM
	a key precursor of	VERY HIGH
	access to	HIGH
C21-C32	according to	MEDIUM
	used to	MEDIUM
	embodied in	HIGH
C21-C33	found to be	HIGH
	directive effect	MEDIUM
	prompted by	HIGH
C21-C34	facilitate	HIGH
	related to	MEDIUM
	as a basic	MEDIUM
C21-C35	needed for	MEDIUM
	lies in	HIGH
	support	HIGH
C41-C42	statistically significant	MEDIUM
	foundational	VERY HIGH
	strong connected	VERY HIGH
C41-C43	improve	MEDIUM
	dependent	MEDIUM
	benefit	MEDIUM
C31-C35	valuable for	MEDIUM
	led to	HIGH
	indicate	HIGH

(continued)

Table 12.14 (continued)

Edge of FCM	Keyword	Linguistic term
C31-C32	representative	HIGH
	based on	MEDIUM
	significance	MEDIUM

Table 12.15 Categorization of keywords based on linguistic terms

Linguistic term		Keyword	
VERY LOW	no significant correlation	no interrelationship	
LOW	an aspect of	week relationship	are as likely to
	obvious	intersection	linked to
	partly represented	widely identified as	may affect
	partially predicted by		
MEDIUM	a field of	accelerate	important element
	enable	important	display
	taken into consideration	never an empty mind of	statistically significant
	according to	as the basis	dependent
	needed for	spontaneously	benefit
	connects to	able to	valuable for
	directly	used to	based on
	commonly used	correlated	significance
	directive effect	a significant	interleave
	related to	common view	driven by
	as a basic	interpreted to	
	improve		
HIGH	prompted by	a key for	demonstrates
	most common view	dominated by	can be important
	facilitate	result from	a key strategic
	lies in	referred to	component
	support	access to	measures of
	led to	core capabilities	indicate
	important	embodied in	found to be
	result in	representative	
VERY HIGH	must entail	strong connected	foundational
	been central to	a key precursor of	

Where n stands for the sum-total of fuzzy sets, N is the sum total of fuzzy variables, and, $_{Ak}$ (x_i) is the membership function for the k-th fuzzy set.

12.3.2 Data Analysis

12.3.2.1 Fuzzy Cognitive Map Results

As stated before, each edge, at least three linguistic terms are assigned to, even, for a few edges, four linguistic terms are assigned to.

A standard fuzzy set operation will be used, which is a standard union. Where,

$$\mu_{A\cup B}(u) = \max\{\mu_A(u), \mu_B(u)\} \tag{12.11}$$

To illustrate, there are the three linguistic terms assigned to the edge of C22-C, they are: "LOW", "VERY LOW", and "VERY LOW".

$$\begin{aligned} A1 &= \tfrac{1}{2} * [(0.25 - 0) + (0 - 0)] * 1 = 0.125 \\ A2 &= \tfrac{1}{2} * [(0.5 - 0) + (0.25 - 0.25)] * 1 = 0.25 \\ A3 &= \tfrac{1}{2} * [(0.25 - 0) + (0 - 0)] * 1 = 0.125 \end{aligned} \tag{12.12}$$

The center of area of the fuzzy set C1 is $\overline{x}_1 = (0.25 + 0)/2 = 0.125$, similarly $\overline{x}_2 = 0.25, \ \ \overline{x}_3 = 0.125$.

Now, the calculated defuzzified value $x^* = \frac{(A_1\overline{x}_1 + A_2\overline{x}_2 + A_3\overline{x}_3)}{A_1 + A_2 + A_3} = 0.1875$.

A final version of the calculated fuzzy cognitive map is presented in Fig. 12.13. This FCM is drawn with software "Mental Modeler".

The following FCM weights are calculated based on the de-fuzzified values of the FCM. A summary of the calculation results is presented in Table 12.16. Table 12.17 provides the corresponding adjacency matrix of the FCM. This matrix can be used to describe the interrelations between the concept.

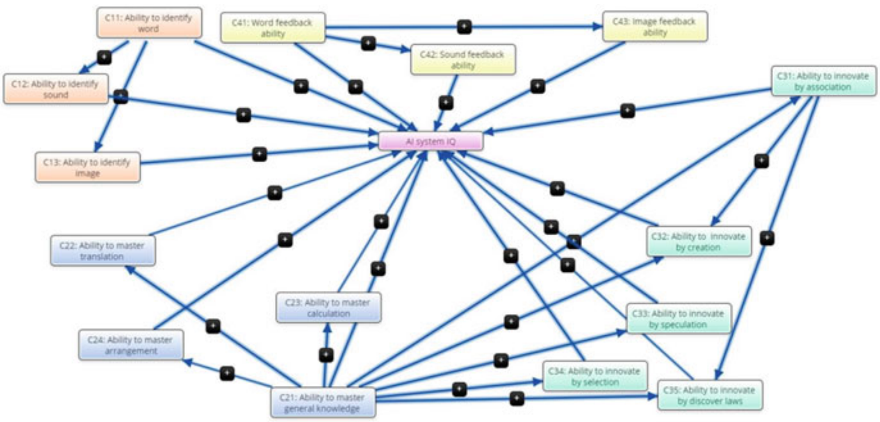


Fig. 12.13 Fuzzy cognitive map with positive/negative sign to edges

Table 12.16 Edge with its calculated weights

Edge of FCM	Defuzzified value	FCM weight	Delphi weight (%)
C11-C	0.5	6.0373%	3
C12-C	0.6786	8.1939%	3
C13-C	0.5833	7.0432%	4
C21-C	0.5625	6.792%	6
C22-C	0.1875	2.264%	3
C23-C	0.45	5.4336%	6
C24-C	0.5	6.0373%	5
C31-C	0.6071	7.3305%	12
C32-C	0.7961	9.6126%	12
C33-C	0.8125	9.8107%	12
C34-C	0.5	6.0373%	12
C35-C	0.4167	5.0315%	12
C41-C	0.5	6.0373%	3
C42-C	0.5	6.0373%	3
C43-C	0.6875	7.3305%	12
C11-C12	0.6525	N/A	0
C11-C13	0.5	N/A	0
C21-C22	0.5625	N/A	0
C21-C23	0.5	N/A	0
C21-C24	0.4	N/A	0
C21-C31	0.7015	N/A	0
C21-C32	0.6071	N/A	0
C21-C33	0.6875	N/A	0
C21-C34	0.6071	N/A	0
C21-C35	0.6875	N/A	0
C41-C42	0.6525	N/A	0
C41-C43	0.5	N/A	0
C31-C35	0.6875	N/A	0
C31-C32	0.6071	N/A	0

12.3.2.2 FCM Steady-State Analysis

A general descriptive summary about this FCM is shown in Table 12.18. The connection and component number are not extremely high. All the components can be categorized into the four groups. All the connections are supported by literature references. There are some interdependencies between the components in the same group. Also, there are some interconnections between components of different groups.

Figure 12.13, which is the merged FCM, shows the density changed to 0.121 while the average connections per component increased to 1.8125. Hierarchy Index is another complexity measurement of FCM. Hierarchy Index is answerable to all the concepts' out-degree in an FCM of N components [62]. Below is the equation

Table 12.17 Adjacency matrix collected from the fuzzy cognitive map

	C11	C12	C13	C21	C22	C23	C24	C31	C32	C33	C34	C35	C41	C42	C43	AI system IQ
C11	0	0.65	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5
C11	0	0.65	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5
C12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.68
C13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.58
C21	0	0	0	0	0.56	0.5	0.4	0.7	0.61	0.69	0.61	0.69	0	0	0	0.56
C22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.19
C23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.45
C24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
C31	0	0	0	0	0	0	0	0	0.61	0	0	0.69	0	0	0	0.61
C32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
C33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.81
C34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
C35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.42
C41	0	0	0	0	0	0	0	0	0	0	0	0	0	0.65	0.5	0.5
C42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
C43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.69
AI system IQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 12.18 General FCM statistics

FCM properties	Value
Total components	16
Total connections	29
Density	0.121
Connections per component	1.8125
No. of driver components	3
No. of receiver components	1
No. of ordinary components	12
Complexity score	0.3333

of Hierarchy Index.

$$h = \frac{12}{(N-1)\,N\,(N+1)} \sum_{1}^{N} \left[\frac{od(vi) - \left(\sum od(vi)\right)}{N} \right]^2 \tag{12.13}$$

Where N is the total number of components. And, od(vi) is the row sum of absolute values of a variable in the FCM adjacency matrix.

If h is close to 1, the FCM is supposed to be completely dominant (hierarchical). If h is close to 0, the FCM is supposed to be completely adapted eco-strategies (democratic) [63]. This FCM's hierarchy index is 0.326, which means, the FCM is much more adaptable to component changes because of its high level of integration and dependence. Also, the in-degree and out-degree of these nodes makes the FCM more democratic, and its system's steady-state more resistant to the alterations of individual components.

The component with the highest centrality was the "AI SYSTEM IQ" with a high score of 8.29. Also, the top three central components directly affecting the "AI SYSTEM IQ" component was the following, in ascending order of their complexity: Ability to innovate by discover laws 1.799, Ability to innovate by association 2.609, and, Ability to master general knowledge 5.319. A higher value means greater importance of an individual concept or several concepts in the overall model (Table 12.19).

12.3.3 Dynamic Scenario Analysis of the AI System IQ

12.3.3.1 Worst and Best-Case Scenario

The above AI system IQ FCM (Fig. 12.13) shows its complexity. This research also conducted dynamic case scenario analyses along with inference simulation.

To start the analysis, we initially apply the current FCM. Both the worst and best scenario will be examined. After that, some insightful results and conclusions can

Table 12.19 Characteristic, type of concepts, in degree, out degree, centrality and in the FCM

Characteristic	Indegree	Outdegree	Centrality	Type
AI system IQ	8.29	0	8.29	receiver
C11	0	1.65	1.65	driver
C12	0.65	0.68	1.33	ordinary
C13	0.5	0.58	1.08	ordinary
C21	0	5.319	5.319	driver
C22	0.56	0.19	0.75	ordinary
C23	0.5	0.45	0.95	ordinary
C24	0.4	0.5	0.9	ordinary
C31	0.7	1.909	2.609	ordinary
C32	1.22	0.8	2.02	ordinary
C33	0.69	0.81	1.5	ordinary
C34	0.61	0.5	1.109	ordinary
C35	1.38	0.42	1.799	ordinary
C41	0	1.65	1.65	driver
C42	0.65	0.5	1.15	ordinary
C43	0.5	0.69	1.19	ordinary

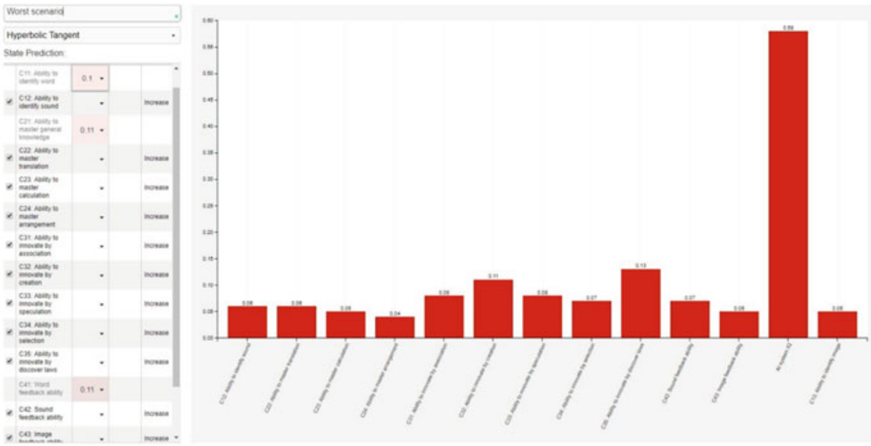


Fig. 12.14 The driver concept effects for the worst scenario

be made. Based on our knowledge, the worst scenario means all the driver concepts are equal to 0.1. And, the best scenario means all the driver concepts are equal to 1.

From Fig. 12.14, it can be observed that there is approximately 58% increase in the "AI system IQ" in the worst scenario while compared to the initial steady-state scenario as the benchmark. Respectively, the "Ability to innovate by discover laws" has an increase of 13%, the "Ability of innovate by creation" has an increase of 11%. All the other concepts have an increase between 4% and 8%. The results also show that all concepts have a positive causality. Furthermore, all of the slight increases for all the ordinary concepts are related to the small increase of driver concepts.

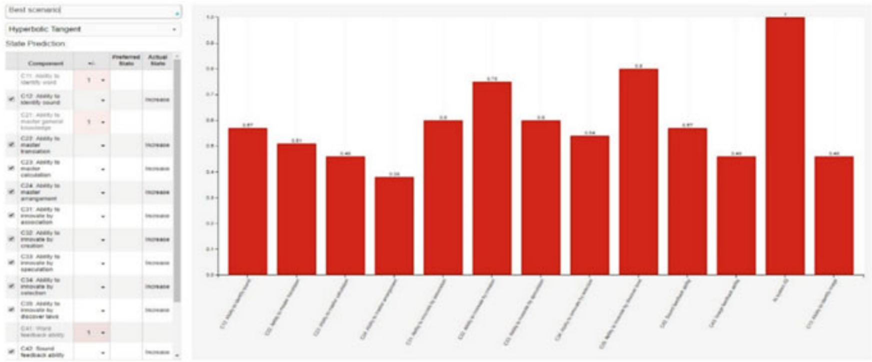


Fig. 12.15 The driver concept effects for the best scenario

Alternatively, all the driver concepts can be set as primarily affecting the FCM's ordinary concepts if all the values are set up with 1. From Fig. 12.15, we found that the "AI system IQ" in the best scenario while compared to the initial steady-state scenario as the benchmark, has a 100% increase. Similarly, the "Ability of innovate by creation" has an increase of 80%, and the "Ability to innovate by discover laws" has an increase of 75%. All the other concepts have an increase between 38% and 60%. This result also supports the conclusion of positive causality. Based on the results, the "Ability of innovate by creation" and "Ability to innovate by discover laws" has the most significant relevance impact.

12.3.3.2 FCM Inference Simulation

Based on the corresponding adjacency matrix (Table 12.19), there are some interrelations between concepts of this FCM. The value Ai of Ci is computed at each simulation step and it basically infers the influence of all other concepts Cj to Ci. This research selected Standard Kosko's activation rule inference method, below is the activation function:

$$A_t\,(K+1) = f\left\{\sum_{j=1,\,j\neq i}^{N} W_{ji} * A_j(k)\right\} \tag{12.14}$$

Also, the threshold function uses the sigmoid function, which shown as:

$$f(x) = \frac{1}{1+e^{-\lambda x}} \tag{12.15}$$

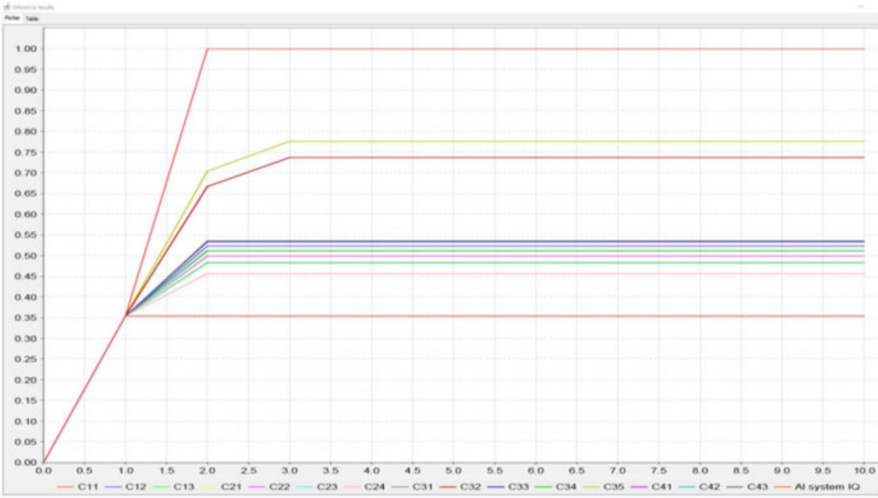


Fig. 12.16 Simulation activation level values per each iteration

Where x is the value Ai(K) at the equilibrium point, and is a real positive number λ that determines the steepness of the continuous function f. Using sigmoid threshold ensure that the activation value belongs to the interval [0, 1].

When running the simulation, all the concepts were assigned an initial value of 0. After a few simulation steps, all the values were expected to be convergence status. Theoretically, after reaching the equilibrium end states, larger activation value means playing a more important role in this FCM. All the driver and ordinary concepts were used for the simulation task. Figure 12.16 shows the corresponding concept activation levels per each iteration with all 18 concepts ranging from 0 to 1. Table 12.20 gives us the inference concept values. All the inference simulations were run through "FCM Expert" software in this research.

Based on the plotter and the table results illustrated by the inference simulation process, it is easy to confirm that the top two critical roles are "C32: Ability to innovate by creation" and "C35: Ability to innovate by discover laws".

In Sect. 12.1, AI system-based search engines IQ is tested based on the Delphi weight approach [38]. Now the new weight calculated through FCM approach is compared to its original subjective approach and two other approaches while using the same data set as the input. Mean Square Error (MSE) is used here as a performance indicator, its equation can be found as below:

$$MSE = \frac{1}{N}\sum_{i}^{N}\left(y_i - \hat{y}_i\right)^2 \tag{12.16}$$

Table 12.21 presents the MSE value for each approach. Dichotomous and polytomous [41] are two other old school methods. For the purpose of choosing the

Table 12.20 Inference concepts values

Step	C11	C12	C13	C21	C22	C23	C24	C31	C32	C33	C34	C35	C41	C42	C43	AI system IQ
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354	0.354
2	0.354	0.522	0.482	0.354	0.498	0.482	0.456	0.536	0.667	0.533	0.512	0.704	0.354	0.522	0.482	0.999
3–8	0.354	0.522	0.482	0.354	0.498	0.482	0.456	0.536	0.736	0.533	0.512	0.776	0.354	0.522	0.482	1
9	0.354	0.522	0.482	0.354	0.498	0.482	0.456	0.536	0.736	0.533	0.512	0.776	0.354	0.522	0.482	1
10	0.354	0.522	0.482	0.354	0.498	0.482	0.456	0.536	0.736	0.533	0.512	0.776	0.354	0.522	0.482	1

Table 12.21 MSE results for four methods

Approach	MSE
Delphi weight	37.63363
Polytomous	49.51347
Dichotomous	31.23294
FCM approach	19.16389

best approach, MSE works as a prediction error indicator here. It is to say, lowest MSE value means less prediction error. Based on MSE values, it is easy to say FCM approach is among the four approaches.

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