Available online at www.ijpe-online.com

International Journal of Performability Engineering

vol. 15, no. 2, February 2019, pp. 654-666
DOI: 10.23940/ijpe.19.02.p30.654666

Intelligence to Artificial Creativity

Qinyun Liu[a], Lin Zou[a], Sicong Ma[a,*], and Hongji Yang[b]

[a]*Centre for Creative Computing, Bath Spa University, Bath, SN13 0BZ, England, UK*
[b]*Department of Informatics, University of Leicester, Leicester, LE1 7RH, England, UK*

Abstract

Assuming creativity is not the same as intelligence and we know that intelligence can be generated by computing (AI), can we generate creativity with computing and call it Artificial Creativity (AC)? What is the connection between AI and AC? This article is attempting to answer these questions and to is propose a system to generate creativity. Human intelligence has been researched for years by psychologists and biologists. Then, based on working mechanism of human brain, computer scientists developed neural network algorithm and other machine learning algorithms to generate intelligence. Creativity is a unique characteristic of living creatures. Recently more work has been on generating creativity through combining creativity theories and artificial intelligence algorithms.

Keywords: artificial intelligence; artificial creativity; creative computing; neural network

(Submitted on November 20, 2018; Revised on December 13, 2018; Accepted on January 14, 2019)

1. Introduction

Creativity has been mentioned and studied for years by humans. Creativity could be seen as the motivation of society progression. Even though artificial intelligence has been proven to work for complex calculations, creativity cannot be completed by computers. Based on the characteristics of intelligence, such as logical, linguistic, special, and so forth, artificial intelligence has achieved intelligence by using algorithms. Some complex calculations, data analysis, and language processing can be completed by computers. For instance, being logical can be achieved by perceptron machines. Linguistic ability, translation, and human-machine interactions can be achieved by natural language processing (NLP). Complicated data analysis can be achieved through using statistical machine learning. Some manufacturing activities can be done by machines based on computer software, such as car assembly and microchip manufacturing, which can be completed by robotic arms. However, intelligence activities being completed by computers or robotic entities are regarded as kinds of representative actions. The result of the actions or the solution methods of the problems have existed. Computers are a workspace or a machine for people to achieve ideas in more effective and accurate ways. Therefore, they are a way to achieve ideas rather than create ideas.

Creativity is a unique character of human beings, and machines can rarely generate creative ideas by using algorithms. On the research of creativity, many scholars have contributed to the core theories and methods for creativity achievement. Boden stated that creativity can be achieved by three methods, which are the combinational method, transformational method, and exploratory method. Creativity ideas are often achieved by people in these three ways. Sternberg and other scholars explained that creativity could be achieved through divergent thinking and convergent thinking. Caliusco and Stegmayer attempted to find a way to combine semantic web and the neural network algorithm. Semantic web is generated to build connections between different notions and is an estimation imitation of divergent thinking. Meanwhile, reasoning can be achieved by semantic web after representation is achieved. Neural networks are built to complete complicated calculations. Concepts and relevant relationships between them can be built by the semantic ontology. The integrated method can discover the knowledge or ideas for the user’s requirements among the heterogeneous domain information. Some of the results may be creative.

* Corresponding author.
E-mail address: Qinyun.liu15@bathspa.ac.uk

According to the proposed research on artificial intelligence and creativity, a system, which can achieve artificial creativity by using relationships between intelligence and creativity, will be built. Machines could be made to achieve creativity, including creative ideas, creative guidance, or inspiration, by using heuristic methods.

To achieve creativity, the relationships between intelligence and creativity should be discovered. The kernel algorithms are extracted from the relationships between intelligence and creativity. Based on the Wallas four steps creativity achievement process, preparation, incubation, illumination, and verification, the whole system includes four components, which are the query analysis component, module expansion component, creative guidance generation component, and integration and validation component.

To explain the artificial creativity system specifically, this paper is divided into seven parts, which are the introduction, intelligence and artificial intelligence, relevant research on creativity, connection between creativity and artificial intelligence, artificial creativity: creativity generation, case study, and conclusion.

2. Intelligence and Artificial Intelligence

Human intelligence has been researched for decades. The multiple intelligence theory by Gardner explains that human intelligence includes eight distinguished kinds of intelligence, i.e., linguistic (poem or story writing), logical mathematics (logical and mathematical problems solving), spatial (ability of getting the lay of the land in a new area, bodily-kinesthetics), musical (composing or playing musical instruments), interpersonal (discovering an effective way to interrelate to others), intrapersonal (reaching a higher level of self-understanding), and naturalist (seeing complicated patterns in the natural environment) [1-2]. Several eminent people, who have made great contributions to different subjects and performed creative thoughts and behaviours, were analysed by Gardner [3]. Individuals are specialised in the eight-multiple intelligence, including Sigmund Freud (intrapersonal), Albert Einstein (logical mathematical), Pablo Picasso (special), Igor Stravinsky (musical), T. S. Eliot (linguistic), Martha Graham (bodily-kinesthetic), Mohandas Gandhi (interpersonal), and Charles Darwin (naturalist) [3]. Gardner stated that most of the eight individuals could achieve creativity in specialised subjects; however, they had weaknesses in other subjects as well [1]. Multiple intelligence can be applied for creating novel ideas, which can be defined as a kind of creativity. Gardner stated that creativity is beyond the intellectual [2]. The eminent people have two major themes, which are having support at their creative breakthrough point and driving a “Faustian Bargain” [2]. Even though creative giants are addicted to generating creativity in related fields, support is required. Meanwhile, life pleasure is given up during this process [2].

Cattell supported the multiple intelligence theory [4-5], including verbal, numerical, spatial, perceptual speed, speed of closure, inductive reasoning, deductive reasoning, rote memory, mechanical knowledge and skill, word fluency, ideation fluency, restructuring closure, flexibility versus firmness, general motor coordination, manual dexterity, and musical pitch [5]. Human intelligence can be concluded into these categories and could be achieved by computers based on algorithms.

Cattell believed that the creative ability was influenced by general intelligence primarily, especially fluid intelligence, as opposed to crystallised intelligence. Then, the creative ability can be determined by personal factors [4].

Guilford stated that intelligence consists of three categories, i.e., operations, content, and products [6-8]. Operations include cognition, memory, divergent production, convergent production, and evaluation [8]. Basic cognitive abilities and memory abilities make people smart. People can recognise entities in the world with cognitive ability and store them into memory (short-term memory or long-term memory) [7]. As can be seen in Figure 1, Piaget elaborated on the cognitive process of the human brain in a logical way. He stated that the development of human thought could be influenced by interactions between four elements: maturation, physical experience, social transmission, and equilibration [9]. Based on Piaget’s theory, the cognitive development process can be explained as a workflow about balancing the cognitive equilibration in the brain (Figure 1). People usually recognise new entities with maturation experience, physical experience, and learning from social transmission. If people generate new schemes through these three ways, new schemes about the new entity are recorded in the brain to reach a new equilibration, which is the process of memorising. Similarly, computers have a storage area, CPU, and interface for recognising information. It is a kind of heuristic process to imitate human intelligence to reach artificial intelligence.

The second category stated by Guilford is content. Figural, symbolic, semantic, and behavioural belong to the content category [8].

The third category consists of products, including units, classes, relations, systems, transformations, and implications [8].

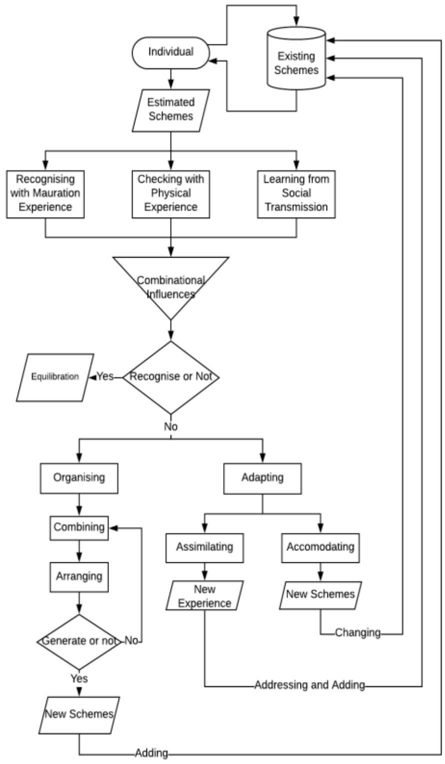

Figure 1. Jean piaget cognitive process

Sternberg generated the triarchic process model to achieve intelligence abilities, i.e., synthetic ability, analytical ability, and practical abilities [10].

The synthetic ability of a creative individual is to redefine the problem in a distinguished way [10]. Redefining a problem is not only an ability, but also an attitude, which can generate new ideas guiding in totally a different way and assist the individual solving the problem effectively [10-13].

The synthetic part of the intelligence, which can be applied to achieve creativity, involves three knowledge acquisition components: selective encoding, selective combination, and selective components [14]. Selective encoding means distinguishing the related information from the unrelated information [14-15]. Selective combination means to combine related information in a creative way [14]. Selective comparison can connect new information to old information in a creative way [14]. For example, Bohr's model regarding to the atom is a miniature version of the solar system, which is the result of applying selective comparison insights [16].

Another aspect of intelligence is the analytical part of intelligence, which is included in creativity [14]. The analytical part is measured in part by conventional tests of intelligence [14]. This aspect is required to judge the value of each idea and determine which one is worth pursuing [15]. When the valuable one is found, the analytical ability can be used to assess the strengths and weaknesses of the idea and discover ways that the worthy idea can be achieved [15].

The third aspect of intellectual ability is the practical ability, which can help individuals apply intellectual skills in any context [14]. As the creative ideas are difficult to be accepted, it is essential for individuals to learn how to communicate the ideas effectively and how to persuade others to accept the ideas [16-18].

Based on the theories and methods stated above, most of the human intelligence can be achieved by artificial intelligence (AI) [19]. Imitating the way people generate intelligence, computer can have logic, knowledge calculation abilities, and reasoning abilities. AI can perform better than human beings in some respects. Heuristic algorithms, such as neural network, ant colony optimisation, and genetic algorithm can be used to achieve bionics [19]. For example, the linguistic ability can be achieved by the natural language process, and logical mathematics can be achieved by neural network algorithms [19-21]. Natural language process is a tool that could replace translators, subtitle groups, and other language area professions. Accurate and effective computing can be achieved by machine learning, and the ability of "learning", such as playing the game of go, is achieved by machines by building the multi-layer neural network algorithm

[22-23], e.g., Alpha Go, where the main methods used are the deep neural network algorithm and heuristic searching algorithm, based on the Monte Carlo Tree searching [22-23]. Furthermore, combined with robots, more intelligence activities can be achieved by computer algorithm and AI. For example, the Boston Dynamics robot can currently achieve some general actions that people usually do. One of the robot types, which looks like humans, is named Atlas. Atlas is the latest in a line of advanced humanoid robots that have been developed by Boston Dynamic. The whole-body mobile operation can be achieved through a control system of Atlas with arms, a torso, and legs. The reaching and workspace of Atlas have been expanded in this way. The hardware of Atlas is made by 3D print, which can reduce the weight and space. This method results in an excellent compact robot. Stereo vision and sensors connected with conventional neural networks can achieve recognition of entities and environments around the robot. In this method, Atlas can travel on unfamiliar terrain. This is a brilliant combination of AI algorithms and hardware. However, even though it is extraordinary enough for a robot, what it has done is what already exists. Even though a good progress has been made in AI, creativity is still to be studied [23].

3. Relevant Research on Creativity

Creativity has been researched by several scholars. The foremost components in the pragmatic approach come from the work of De Bono, who focused on lateral thinking and other aspects of creativity research, leading to commercial success [24]. De Bono was concerned more about practice than solely theories [25]. His approach focused on aspects of an idea, such as PMI representing pluses, minuses, and interesting, and using the word po, which was derived from words like hypothesis, suppose, and poetry [24]. In this way, people can be provoked by the abbreviation or part of the word to create more ideas, which may be better than teaching the words [24].

Guilford found that divergent thinking and convergent thinking could be effective for creative idea generation [6-7]. Wallas stated that to achieve creativity, four steps are needed, i.e., preparation, incubation, illumination, and verification [19]. These four steps are implemented in this research as the basis for achieving an artificial creativity system.

Sternberg and Lubart suggested that creativity requires six sources, i.e., intelligence, knowledge, thinking styles, personality, motivation, and the environment [26]. They posited creative activity as an investment process. Creative people are regarded as investors [26]. Each creative idea could be pursued by the masses until it is implemented in target industry production. Similar with investors in the stock market, people with creative ideas "buy low and sell high" [26]. This process should be experienced as a process of defying the crowd.

The Geneplore model divides a creativity process into the generative phase and the explorative phase [27-28]. An individual constructs mental representation, which can allow the properties to promote creative discoveries [28-30]. In the exploratory phase, these properties can be used to build creative ideas. The process of retrieval, association, synthesis, transformation, analogical transfer, and categorical reduction can be used for creative invention [27]. Relevant algorithms can be related to transfer these theories to methods.

Boden stated three methods to achieve creativity, i.e., the combinational method, transformational method, and exploratory method [31]. To apply the creativity theory, the theories should be related to algorithms. For example, Boden's theory can be transferred into research on conceptual space. Changing the conceptual space of the dataset can create novel data units based on the creative computing theory [32-34]. Therefore, new conceptual space can be generated by combining unrelated data based on the combinational method, changing principle components of data units based on the transformational method, and reducing principle components by using exploratory-based methods. Novel conceptual space is represented by data unit form.

4. Connection Between Creativity and Artificial Intelligence

The relationships between creativity (C) and intelligence (I) have been discussed by scholars. Some considered that creativity and intelligence are the same, while others considered them as different. To summarise, the possible connections about the relationships can be [35]:

Intelligence is a subset of creativity: $I \subset CI \subset C$;

Creativity and intelligence are overlapping sets: $I \cap C = \text{set } AI \cap C = \text{set } A$;

As intelligence can be achieved by machines to some extent based on the research on artificial intelligence, creativity is unable to be generated by machines currently, and it cannot be regarded as a subset of intelligence. Based on the human intelligence generation process, knowledge and non-logical thinking processes are necessary for creative idea generation. Therefore, the relationships between intelligence and creativity cannot be disjoint. Furthermore, intelligence has a different definition compared with creativity. Intelligence is regarded as repeating existing issues in a more effective or beneficial way. Creativity is regarded as generating new issues. Three basic elements for creativity are novel, useful, and surprising. Thus, intelligence can be an important element to generate creativity.

The relationships between intelligence and creativity are supported by different theories.

To the point that intelligence is the subset of the creativity, Smith's hierarchy theory, which is based on Bloom's taxonomy of educational objectives, provides support. The theory is mainly about the cognitive process. Taxonomy posited that the cognitive process can be a combination of cumulative and hierarchical continuum. The whole process starts with knowledge and proceeds with comprehension, application, analysis, synthesis, and evaluation. The first four elements are intellectual ability and the last two are creative ability, which require the potential skills in intelligence and generating creativity [36].

To the point that intelligence and creativity are overlapping sets, in this point of view, the creativity is similar with the intelligence in some respects. However, in the other aspects, they are different. Barron stated that if the definition of originality (creativity) was the ability to solve problems in an adaptive and novel way, and the definition of intelligence was the ability to solve the problems, then the manifestation of intelligence is similar with the manifestation of originality [37]. Some other scholars suggested differences between intelligence and creativity [37]. Roe stated that the creativity solution for the problem is characterised by novelty, unconventionality, persistence, and difficulty [37]. These characteristics are illogical and disordered ones. However, the general problem solution is a specific one and needs logic and order to complete the goal [37]. That is the major differentiation. Meanwhile, the creative process is noncognitive and emotional, which is an obstacle for effective problem-solving [37].

Haensly and Reynolds stated that creativity and intelligence can be regarded as a "unitary phenomenon". These two can consist of a conjoint set. Creativity can express intelligence [38]. Weisberg and Langley suggested that creativity was the ordinary process that could generate extraordinary results combined with intelligence elements [39]. Perkins stated a theory of nothing special. If an individual wants to be creative, he/she is required to solve ordinary problems [40].

Cox generated an estimation of intelligence quotient for 301 of the most eminent individuals living between the years of 1450 and 1850 [25]. To rank the eminence, Cox worked with Terman and Merill to examine several elements that may influence the intelligence of the eminent people, such as biographies, nature of earliest learning, age of first reading and of first mathematical performance, amount and character of the reading, and so on [41]. Eventually, Cox found the correlation of the intelligence quotient, and the rank order in the list is 0.16, plus or minus 0.039 considering the unreliability of the sample data [25].

However, Simonton re-examined the experiment with multiple regression models and concluded that the correlations between the ranking and intelligence could be zero if the birth years of eminent people were considered [41].

Eventually, Cox concluded that a high intelligence quotient (but not the highest one) combined with persistence can achieve more than the highest intelligence quotient with less persistence can [41]. This means that the creativity can be achieved better by the individual with high intelligence plus persistence trait compared with the individual with higher intelligence plus less persistence [25]. Intelligence can be the basis of achieving creativity, but it is not integral to achieve creativity [25].

5. Artificial Creativity: Creativity Generation

This research aims at developing an approach to achieve artificial creativity (machine creativity) to assist human solving problems, with an artificial creativity system built. Based on the progress in artificial intelligence using heuristic algorithms, it is imperative to investigate whether artificial creativity can possibly be achieved similarly. Humans achieve creativity by processing intelligence elements (including knowledge and experience) and non-logical processing by the brain. The proposed focus is on the relationships between intelligence and creativity, leading to an approach to creativity generation. In this system, the input data is the user's requirements and the output results are creative ideas to generate solutions to practical problems.

It is proposed that an artificial creativity system includes four components, which is shown in Figure 2: query analysis component, module expansion component, creative guidance generation component, and integration and validation component, referring to existing research, such as Wallas's four-step creativity generation theory (preparation, incubation, illumination, and verification).

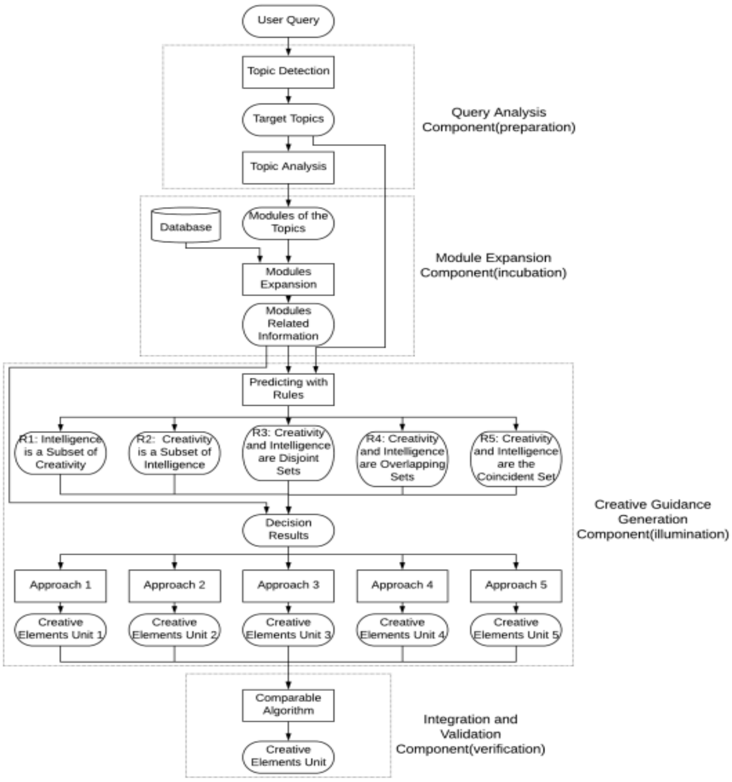

Figure 2. Structure of an artificial creativity system

In the preparation phase, the query analysis component can decompose a query through natural language processing. The query is separated into key words. Modifying words are dropped. Query information represented by key words is used for further processing. In this step, the specific requirement from the user is detected by the topic detection function. The target topics are output and analysed by the natural language processing, based on the Python programming language natural language process toolkit.

Key words are output at the end of this step.

The decomposed query information is expanded through the module expansion component for obtaining more detailed information using semantic web [31]. The general semantic web relationships can be built by using RDF language:

```
<rdf:RDF
Xmlns:mfg="http://www.londonstockexchange.com/statistics/companies-and-issuers/companyonlondonstockexcahnge#"
xmlns: rdf="http://www.londonstockexchange.com#">
<mfg:Company rdf: about=http://www.londonstockexchange.com/statistics/companies-and-
issuers/companyonlondonstockexchange#1pmplc>
<mfg:industry>Financials</mfg:industry>
<mfg:country>UK</mfg:country>

<mfg:region>Europe</mfg:region>
<mfg:marketCap>31.21</mfg:marketCap>
</mfg:company>

<mfg:Company rdf:about=http://www.londonstockexchange.com/statistics/companies-and-
issuers/companyonlondonstockexchange#GLANBIAplc>
<mfg:industry>customerGoods</mfg:industry>
<mfg:country>Ireland</mfg:country>
<mfg:region>Europe</mfg:region>
<mfg:marketCap>3638.24</mfg:marketCpa>
</mfg:company>
```

<mfg:Company rdf:about=http://www.londonstockexchange.com/statistics/companies-and-issuers/companyonlondonstockexchange#GLANBIAplc>
<mfg:industry>customerGoods</mfg:industry>
<mfg:country>England</mfg:country>
<mfg:region>Europe</mfg:region>
<mfg:marketCap>35.87</mfg:marketCpa>
</mfg:company>
</rdf:RDF>

The labels in the RDF represent the relationships between different concepts. The neural network is used to build ontology-matching in the semantic web. High accuracy and efficiency in the ontology-matching can be achieved through the pre-trained neural network algorithm. In this step, the modules of the topics are expanded by using semantic web and connecting with the database. Related information is output after the expansion.

A series of predicting rules are established for judging that the query and relevant information could be processed by which approach(es), based on relationships between intelligence and creativity. The rules can be formulated through possible principles in all areas of knowledge. Five approaches are mapped to relevant relationships to generate creative elements to the user queries. Each approach is based on the theory of the intelligence and creativity relationships. Approaches can be extracted based on the theories and methods of each relationship.

Under the condition of $\mathrm{I} \subset \mathrm{CI} \subset \mathrm{C}$, the intelligence approaches, semantic web, and traditional machine learning algorithms can be used by creativity methods through Boden's theory [31]. The three creative methods of combinational, transformational, and exploratory methods are based on Boden's theory.

Novel units can be generated by combining similar units in the datasets based on combinational-theory.

The association rules learning algorithm is used for generating this approach. In this paper, the FP-growth algorithm is implemented in combination processing. The frequent itemset can be found through a transaction dataset. Association rules can be derived eventually. The general process can be stated as

- $T = \{i_1, i_2, i_3, \cdots, i_m\}$. *A set of items*;
- *Set C is a transaction set*; *each transaction has its own ID number*.
- $\mathrm{t} \subseteq \mathrm{T}$;
- *If* $x \subseteq\subseteq t$; *t contains X*, *which is a set of some items in T*;
- $X \subset\subset T$, $Y \subset\subset T$ & $X \cap\cap Y = \emptyset\emptyset$;
- *The confident c and the support of the relationships s are both in* (0,1) *range*;

When the transaction *C* is given, the association rules of X→ Y→ Y can be generated according to the minimum support and confidence value that the user constitutes.

As can be seen in Figure 3, information units can be categorized into related information, unrelated information, new information, and obsolete information. The FP-growth algorithm can detect association rules between distinct information units through the training sets in the database. Then, the association rules are used for detecting test data connections. The results of this step are two novel combined information sets.

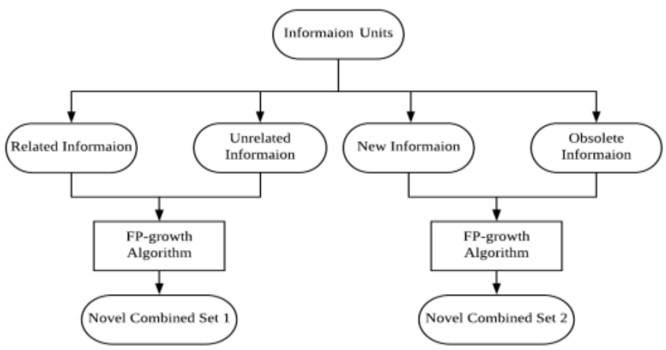

Figure 3. Combinational creativity achievement approach

In the exploratory-method-based approach, which can be seen in Figure 4, the support vector machine (SVM) algorithm is used for classifying. Information units are built as vectors, which are ontology vectors. Support vector machines can classify the ontology vectors into two categories, a category with original information and a category without original information. The main information of the entire information units is extracted from the category with original information, while the categories of units are from the category without original information. The selection is random. To achieve creativity through the exploratory method, the main information should be replaced with other categories of units. In the process of SVM, there are four kernels that have been used for classification and are essential for generating different novel ideas in the exploratory method.

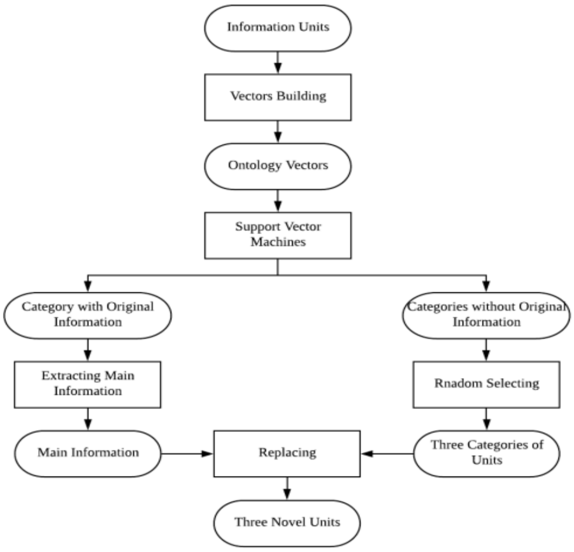

Figure 4. Exploratory-method-based approach

The polynomial kernel of SVM classification is

$$\mathrm{K(x,y)} = (x^T y + c)^d$$

x, *y* are input vectors in the input space. c is the free parameter, which has effects on high order and lower order terms of the polynomial.

In the machine learning area, the polynomial kernel is the basic function that is normally used in the SVM algorithm and other algorithms that are required in the kernel model. Such algorithms aim at discovering similarities between vectors.

The formula for the linear kernel of SVM is

$$\mathrm{K(x,y)} = x^T y$$

The formula for the sigmoid kernel of SVM is

$$\mathrm{K(x,y)} = \tanh(x^T y + c)$$

The formula for the RBF (Radial Basis Function) kernel of SVM is

$$\mathrm{K}(\mathrm{x},x') = \exp(-\frac{\|(x - x'\|^2}{2\partial^2})$$

The transformational-theory-based approach aims at achieving creative results by reducing the conceptual space dimensions. New conceptual structures can be generated, and “surprising” “novel” ideas may be achieved. Principle components analysis can be used to achieve conceptual space reduction.

The Linear Discriminant Analysis (LDA) algorithm is a supervised linear dimension reducing algorithm. Data points in the figure can be processed to be more explicit and identifiable. The original data can be represented as X, matrix m×n, m represents the dimension, and n represents the number of samples. The output data has two characters: data in the same taxonomy are approached and within class, and data in different taxonomies are departed and between class.

The normalised data is delivered to the new space established by the feature vectors. The core code to achieve LDA algorithm is presented:

```
import numpy as np
from sklearn.datasets import load_iris
import matplotlib.pyplot as plt
from sklearn.discriminant_analysis import LinearDiscriminantAnalysis

def LDA_dimensionality(X, y, k):

    label_ = list(set(y))

    X_classify = {}

    for label in label_:
        X1 = np.array([X[i] for i in range(len(X)) if y[i] == label])
        X_classify[label] = X1

    mju = np.mean(X, axis=0)
    mju_classify = {}

    for label in label_:
        mju1 = np.mean(X_classify[label], axis=0)
        mju_classify[label] = mju1

    Sw = np.zeros((len(mju), len(mju)))
    for i in label_:
        Sw += np.dot((X_classify[i] - mju_classify[i]).T, X_classify[i] - mju_classify[i])

    Sb = np.zeros((len(mju), len(mju)))
    for i in label_:
        Sb += len(X_classify[i]) * np.dot((mju_classify[i] - mju).reshape((len(mju), 1)), (mju_classify[i] - mju).reshape((1, len(mju))))

    eig_vals, eig_vecs = np.linalg.eig(np.linalg.inv(Sw).dot(Sb))

    sorted_indices = np.argsort(eig_vals)
    topk_eig_vecs = eig_vecs[:, sorted_indices[:-k - 1:-1]]
    return topk_eig_vecs

if '__main__' == __name__:

    iris = load_iris()
    X = iris.data
    y = iris.target

    W = LDA_dimensionality(X, y, 2)
    X_new = np.dot((X), W)
    plt.figure(1)
    plt.scatter(X_new[:, 0], X_new[:, 1], marker='*', c=y)

    lda = LinearDiscriminantAnalysis(n_components=2)
    lda.fit(X, y)
    X_new = lda.transform(X)
    print(X_new)
    plt.figure(2)
    plt.scatter(X_new[:, 0], X_new[:, 1], marker='*', c=y)
    plt.show()
```

Based on the PCA, new information units can be achieved eventually through conceptual space reducing. The final output of this step can be three units (principal components), and the others are dropped.

Under this relationship, the output results are creative by using intelligence methods guided by creative methods.

Under the condition of $\mathrm{I} \cap \mathrm{C} = \text{set AI} \cap \mathrm{C} = \text{set A}$, the association rule learning will be used to discover the set A based on the problem type and the weight of each element. The ANN will be used to regenerate the weights. Then, each unit ranks the elements (sorting algorithm). The top three of each element will be output, and three sub-units are created.

The five approaches process the information to generate creative units. According to the predicted rules, some of the five approaches are selected to complete the creative guidance detecting process. For example, creative units could be found under the relationships of $\mathrm{I} \subset \mathrm{CI} \subset \mathrm{C}$, $\mathrm{I} = \mathrm{C}$, $\mathrm{I} = \mathrm{C}$, and $\mathrm{I} \cap \mathrm{C} = \text{set AI} \cap \mathrm{C} = \text{set A}$ to solve the query from the user. The expanded information about the topics is processed by these three approaches, and three creative units are output at this step.

To provide high-quality guidance to the user, an integration and validation component is required. Based on the creativity principles and relevant theories, a comparable algorithm is generated in this step, which combines the sorting algorithm and creative methods.

6. Case Study

The simulative user query is about an investment portfolio decision of "How to generate a high benefit investment portfolio in January 2019 within a range of fluctuation of 10%"? After the query is divided and analysed by NLP, "high benefit", "investment portfolio", "January 2019", and "fluctuation of 10%" are output by the artificial creativity system. The information can be expanded through the semantic web technique with a weighted ontology (built by BPNN). The information is from industries, companies, and markets that the companies are in. Information of top 100 companies was selected in this case. Part of the dataset is selected and shown in Figure 5.

FOUR	4IMPRINT GRP.	GBX	85.00	-50	-2.5
888	888 HLDGS	GBX	190.5	-1.5	-0.78
ASBE	A.B.ENGINE ERING	GBX	20	0	0
ABF	A.B.FOOD	GBX	2,329.00	7	0.3
AA.	AA PLC	GBX	100.6	-4.3	-4.1
ANII	AB NEW INDIA	GBX	394	0	0
AAS	ABDN.ASIA N SML	GBX	952	-6	-0.63
AAIF	ABDN.ASN INC	GBX	191.5	1.5	0.79
ANW	ABDN.NEW THAI	GBX	561	0	0
ABD	ABDN.NW. DWN	GBX	204	-0.5	-0.24
AASC	ABERDEEN ASIAN.	GBX	101	0	0
ADIG	ABERDEEN DI&G	GBX	123.5	0	0
AJIT	ABERDEEN JAPAN	GBX	557.5	-2.5	-0.45
ASCI	ABERDEEN SML.CO	GBX	258	0	0
ASLI	ABERDEEN STAND.	GBX	106.75	0	0
ASIT	ABERFORTH SPLI.	GBX	88.5	0	0
ASIZ	ABERFORTH SPLIZ	GBX	106	0	0
ASL	ABERFTH.S MLL.CO	GBX	1,240.00	-16	-1.27
ACA	ACACIA MIN	GBX	140.85	-17.5	-11.05

Figure 5. Part of the target dataset

Under the relationship of $\mathrm{I} \subset \mathrm{CI} \subset \mathrm{C}$, there are three approaches to achieve creativity, which are the transformational method, combinational method, and exploratory method [27].

Initially, companies with fluctuations over 10% are dropped. Leaving the rest of data for further processing, three manners will process the data to output several novel units, which are the basis of investment portfolio.

The expanded information is processed by three sub-approaches in step three. In the combination part, the information of selected information units includes the code, company name, fluctuation percentage, and price of market share.

In the transformation part, the information is transferred to vectors based on the weighted ontology system. The main components of the data can be discovered by machine learning algorithm and linear discrimination analysis. Different categories can be re-combined through the transformational method to compose new units, which are the investment portfolio. Novel units are achieved in this way.

In the exploratory part, the information units are required to be transferred to vectors. Vectors are classified by using Support Vector Machines. There are three kernels used for SVM classification. Different categories are kept for further use. To achieve creativity, the changing conceptual space is working. Different categories can be changed in position to form new units. Based on different kernels, categories are excellent for further operation (instead of two). In this way, more novel units can be obtained by composing different categories. The x-axis represents investment selection preference. The y-axis represents the company market capital. The polynomial kernel of SVM classification is

$$\mathrm{K(x,y)} = (x^T y + c)^d$$

x, *y* are input vectors in the input space. c is the free parameter, which has effects on high order and lower order terms of the polynomial. The display is shown in Figure 6.

The formula for the linear kernel of SVM is

$$\mathrm{K(x,y)} = x^T y$$

The display of SVM with linear kernel is shown in Figure 7.

The formula for the sigmoid kernel of SVM is

$$\mathrm{K(x,y)} = \tanh(x^T y + c)$$

The display of SVM with Sigmoid kernel is shown in Figure 8.

The formula for the RBF (Radial Basis Function) kernel of SVM is

$$\mathrm{K}(\mathrm{x}, x') = \exp(-\frac{\|(x - x'\|^2}{2\partial^2})$$

The display of SVM with RBF kernel is shown in Figure 9.

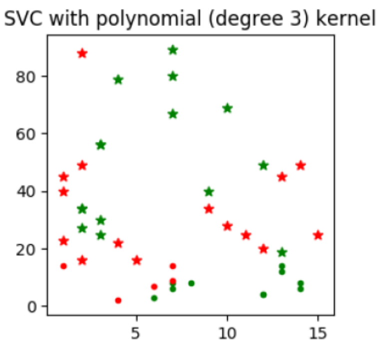

Figure 6. SVM classification results with polynomial kernel

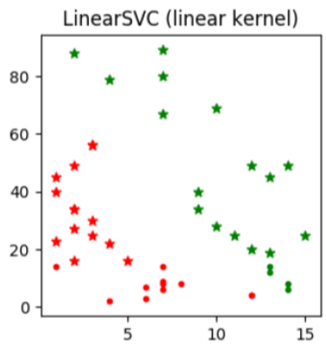

Figure 7. SVM classification results with linear kernel

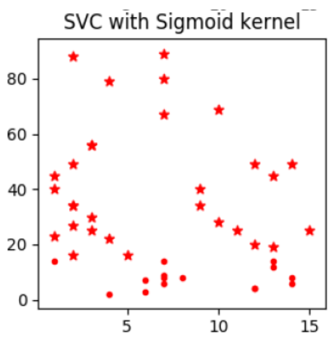

Figure 8. SVM classification results with sigmoid kernel

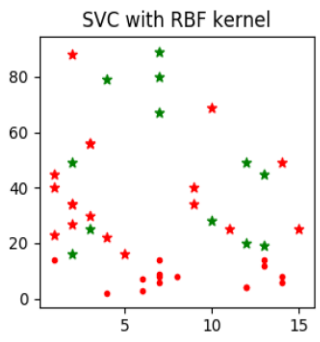

Figure 9. SVM Classification with RBF Kernel

The final output will be nine information units that include the basic concept information and relevant solutions for the query. The comparable algorithm will pick out the suggestions in the output units and select the most appropriate (creative and reasonable) suggestion for the problem.

7. Conclusions

This research aims at detecting artificial creativity system availability. The AC system is used for generating creative ideas by using distinct relationships between creativity and intelligence. Since neural networks were widely accepted, artificial intelligence has been well developed. By using the heuristic theory, creativity can also be achieved in a similar way. However, it is a non-logical process for both humans and computers through comparing creativity and intelligence. The user's requirement is processed by using natural language processing to be divided into topics finding the main principles, which is the query analysis component. Main terms are expanded by using the semantic web. More information is obtained in this step, which is the module expansion component. To discover the artificial creativity system, the relationship between creativity and intelligence is the kernel theory and basis for generating the approaches to output creative results. Five widely accepted creativity and intelligence relationships can be used to create different approaches. Each approach can be extracted based on a relationship. Creative results can be output in this step, which is the creative guidance generation component. To provide the user with the ideal guidance, the integration and validation component is used for comparing the output results to ensure that the best one is output.

Acknowledgements

This work was partially supported by the Open Projects Fund of Key Laboratory of Ecology and Energy-saving Study of Dense Habitat (Tongji University), Ministry of Education (No. 201830301).

References

1. H. Gardner, "Frames of Mind: The Theory of Multiple Intelligences," Basic books, Elsevier, New York, US, 2011
2. H. Gardner, "Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Ghandi," Basic Civitas Books, Elsevier, New York, US, 2011
3. H. Gardner, "Leading minds: An anatomy of leadership," Basic books, Hachette UK, 2011
4. R. Cattell, B. Raymond, "Personality and Motivation Structure and Measurement," American Psychology Association, World Book Co., Oxford, England, 1957
5. R. Cattell, "Abilities: Their Structure, Growth, and Action," American Psychology Association, New York, USA, 1971
6. J. Guilford and P. Christensen, "The One-Way Relation Between Creative Potential and IQ," *The Journal of Creative Behavior*, Vol. 7, No. 4, pp. 247-252, 1973
7. J. Guilford and H. Ralph, "Creative Potential as Related to Measures of IQ and Verbal Comprehension," *Indian Journal of Psychology*, *Indian Psychology Asociation*, Vol. 41, pp. 7, India,1966
8. J. Guilford, "Three Faces of Intellect," *American Psychologist*, *American Psychological Association*, Vol. 14, No. 8, pp. 469, New York, US, 1959
9. J. Piaget, "Piaget's Theory of Cognitive Development," *Childhood Cognitive Development*: *The Essential Readings*, pp. 33-47, 2000
10. R. Sternberg, "The Triarchic Mind: A New Theory of Human Intelligence," Viking Press, Penguin Random House Company, New York, US, 1988
11. M. Brewer, "A Dual Process Model of Impression Formation," Lawrence Erlbaum Associates Inc, American Psychological Association, New Jercy, US, 1988
12. D. Dannefer and P. Marion, "Development as a Multidimensional Process: Individual and Social Constituents," *Human Development*, Vol. 33, No. 2-3, pp. 108-137, Karger, Swizerland, 1990
13. T. Carroll, "The Three-Stratum Theory of Cognitive Abilities," American Psychological Association, New York, US, 2005
14. R. Sternberg, "Successful Intelligence, First Agency Publishing," American Phychological Association, New York, US, 1997
15. R. Sternberg, "Beyond IQ: A Triarchic Theory of Human Intelligence," Cambridge University Press, the Press Syndicate of University of Cambridge, New York, US, 1985
16. R. Sternberg and K. Douglas, "What is Intelligence? Contemporary Viewpoints on its Nature and Definition," Praeger Pub Text, California, US, 1986
17. R. Sternberg and I. Todd, "Investing in Creativity," *American Psychologist*, *American Psycholgical Association*, Vol. 51, No. 7, pp. 677, New York, US,1996
18. R. Sternberg, "Implicit Theories of Intelligence, Creativity, and Wisdom," *Journal of Personality and Social Psychology*, *American Psychology Association*, Vol. 49, No. 3, pp. 607, Washington D.C., US, 1985
19. S. Russell and P. Norvig, "Artificial Intelligence: A Modern Approach," Pearson Education Limited, Malaysia, 2016
20. N. Nilsson, "Principles of Artificial Intelligence," Morgan Kaufmann Publishers, USA, 2014
21. S. Robert, "Algorithms, Addison," Wesley Publishing Company, USA, 2017
22. F. Wang, J. Zhang, et al., "Where Does AlphaGo Go: From Church-Turing Thesis to AlphaGo Thesis and Beyond," *IEEE/CAA Journal of Automatica Sinica*, Vol. 3, No. 2, pp. 113-120, 2016
23. J. Chen, "The Evolution of Computing: AlphaGo," *Computing in Science & Engineering*, *IEEE and American Institute of*

Physics, Vol. 18, No. 4, pp. 4-7, New York, US, 2016
24. E. D. Bono and Z. Efrem, “Lateral Thinking,” Viking, London, UK, 2010
25. J. Han, F. Shi, L. Chen, and P. Childs, “The Combinator–A Computer-based Tool for Creative Idea Generation based on a Simulation Approach,” Design Science, Elsevier, pp. 4, Cambridge, UK, 2018
26. R. Sternberg and R. J. Sternberg, “eds. Handbook of creativity,” Cambridge University Press, Cambridge, UK, 1999
27. R. Sternberg and T. Lubart, “Defying the Crowd: Cultivating Creativity in a Culture of Conformity,” Free Press, American Phychological Association, New York, US, 1995
28. R. Finke, “Creative imagery: Discoveries and Inventions in Visualization,” Psychology Press, Taylor & Francis Co., London, UK, 2014
29. R. Finke, B. Thomas, and M. Steven, “Creative Cognition: Theory, Research, and Applications,” The MIT Press, Plenum Publishing Corporation, Cambridge, MA, US, 1992
30. T. Amabile, G. Phyllis, and C. Shereen, “Social Influences on Creativity: Evaluation, Coaction, and Surveillance,” *Creativity Research Journal*, *Taylor & Francis Co.*, Vol. 3, No. 1, pp. 6-21, UK,1990
31. R. Sternberg and A. Linda, “13 Creativity and Intelligence,” Cambridge University Press, Cambridge, UK, 1999
32. A. Hugill and H. Yang, “The Creative Turn: New Challenges for Computing,” *International Journal of Creative Computing* (*IJCRC*), Vol. 1, No. 1, pp. 4-19, 2013
33. H. Yang, D. Jing, and L. Zhang, “Creative Computing: An Approach to Knowledge Combination for Creativity?” *IEEE Symposium on Service-Oriented System Engineering* (*SOSE*), pp. 407-414, London, UK, 2016
34. D. Jing and H. Yang, “Creative Computing for Bespoke Ideation,” in *Proceedings of IEEE 39th Computer Software and Applications Conference* (*COMPSAC*), Vol. 1, pp. 34-43, Taichung, Taiwan, China, 2015
35. I. Smith, “IQ, Creativity, and the Taxonomy of Educational Objectives: Cognitive Domain,” *The Journal of Experimental Education*, *Taylor and Francis*, Vol. 38, No. 4, pp. 58-60, New York, US, 1970
36. Frank. Barron, “Creativity and Psychological Health,” American Psychological Association, Oxford, England, 1963
37. P. Haensly and C. Reynolds, “Creativity and Intelligence,” Handbook of Creativity, Springer, pp. 111-132, Boston, MA, 1989
38. W. Robert, “Creativity: Genius and Other Myths,” WH Freeman/Times Books/Henry Holt & Co, New York, US, 1986
39. D. Perkins, “The Mind’s Best Work,” Harvard University Press, Harvard University, Harvard, US, 2009
40. C. Cox, “The Early Mental Traits of 300 Geniuses,” *Genius & Eminence*, pp. 53-58, 1992
41. D. Simonton, “Biographical Determinants of Achieved Eminence: A Multivariate Approach to the Cox Data,” *Journal of Personality and Social Psychology*, Vol. 33, No. 2, pp. 218, 1976