

# Another AI? Artificial Imagination for Artistic Mind Map Generation

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## ABSTRACT

This article presents a novel real-time, collaborative, and interactive AI painting system, Mappa Mundi, for artistic Mind Map creation. The system consists of a voice-based input interface, an automatic topic expansion module, and an image projection module. Imagination is one of the most important factors which makes an artistic painting unique and impressive. With the rapid development of artificial intelligence, more and more researchers try to create painting with AI technology. However, lacking imagination is still a main problem for AI painting. This research proposes a novel approach to inject rich imagination into a special kind of painting- Mind Map. Lexical and phonological similarities of respective seed words are first considered, then the system learns and inherits the artist's original painting style, and further applies Dadaism and impossibility of improvisation principles into the process. Several metrics for imagination evaluation are then developed later in the article. The result show that this proposed method can increase the imagination of painting and also improve its overall quality.

## KEYWORDS

AI Painting, Artificial Imagination, Dadaism, Mind Map

## INTRODUCTION

Art and technology have been interweaved in the course of human history. In the Renaissance, the advancement in anatomy led to realistic and perspective depiction of human body. During industrial revolution, the development of photography steered art history away from realism to impressionism and expressionism to capture the beauty of changing nature and inner expression. Nowadays, artificial intelligence (AI) demonstrates stronger potential for art creation. Many researches have been conducted to involve AI into poem generation (Zhang & Lapata, 2014; Cheng et al., 2018), creation of classical or pop music (Thakkar et al., 2018; Hadjeres et al., 2017) and automatic images generation (van den Oord et al., 2016; Yan et al., 2016; Xu et al., 2018).

Whereas there are fewer researches exploring the possibility of artificial imagination. In this paper, we want to shed light on if AI has imagination, and we tackle a more challenging task: the generation of Mind Map with a given topic or an idea. Firmly implanted in a scientific epistemology, a map is viewed as a representation of knowledge. Whereas a Mind Map is an artistic representation

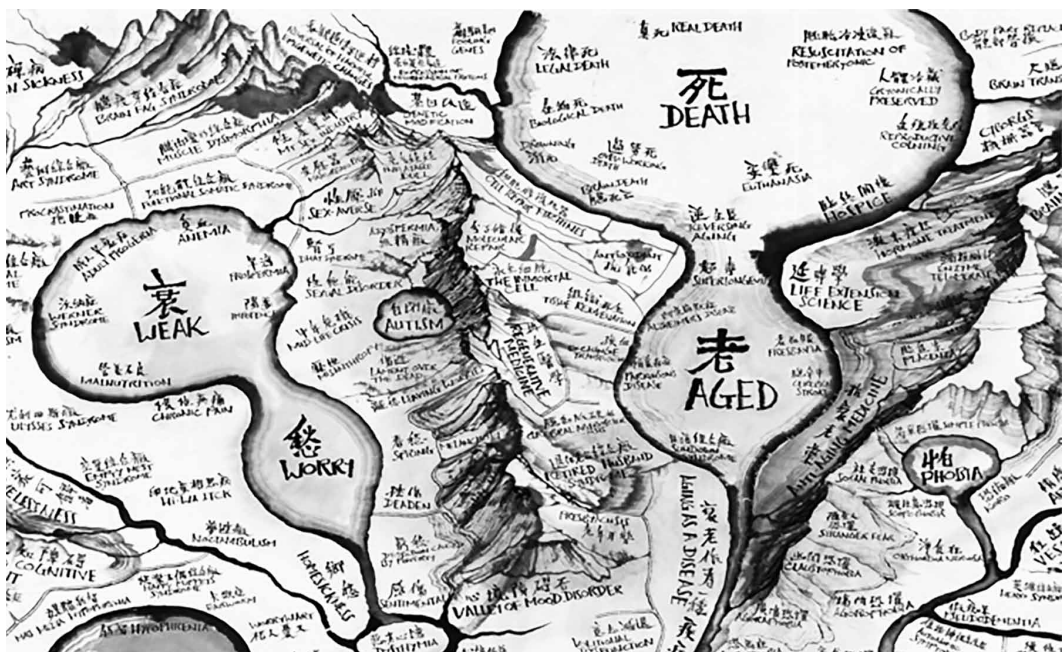
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to visualize the abstract information in a figurative way (shown in Figure 1). Sharing the same form with conventional maps, Mind Map is a special diagram which connects and arranges related words, terms and ideas around a central keyword or idea (Hopper, 2012). Thus, the core issue for Mind Map creation is the information expansion, that is, given a keyword or idea, how to extend it with more ideas, concepts or ontologies. In that case, during this research, instead of discussing the drawing techniques for the visual representation of Mind Map, we focus on the AI-enabled imagination for concepts, ideas and all forms of information expansion in Mind Map.

Currently, research on word expansion, which mainly are based on word embedding techniques (Pennington et al., 2014), are a knowledge aggregation rather than imagination. To generate an imaginative and creative Mind Map, we are facing the following challenges. First of all, language is an informative and yet complex system for human mind expression. Words and their relations should be extended with a myriad level of information, such as the lexical, phonologically, psychological features. How to expand imagination beyond the semantic boundary is the first concern in this research. Secondly, same with other artwork, Mind Map needs to reflect individual artist's mind, understanding and experience of the world. The concept of imitation also laid the historical foundations in both Chinese and Western art (Xie, n.d.; Coleridge, 1984). The second challenge is how to teach AI to learn from artist's mind, knowledge, and experience during the Mind Map creation. Last but not least, unlike cartographers, artists pay less attention on neither following the convention nor defining accurate relation between concepts. Instead, they plant the seed of artistic free play of imaginations when defining connections between objects or concepts. The imaginative connections between literal representations and the metaphorical interpretations create possibility to semantic expansion which flourished artistically. Our third challenge is how we can transcend from simply following the convention rules to breaking the restrictions of domain, categorical information and regular convention.

To solve above challenges, we propose an AI injected Mind Map generator, Mappa Mundi. Specifically, to better imitate artist's idea and knowledge in AI creation, we propose to establish a knowledge graph by extracting author's ideas and thinking. Further, we break domain and restrictions

Figure 1. An Example of mind map



for word expansion and try to explore more possibilities for words connection by creating rules influenced by the Dadaism.

The contribution of this research is in three-fold:

- We provide a framework to understand how AI can aid in artistic practice. AI in art has more implications than a way of artistic creation, and it enriches the possibility of artistic practice. Further, when involved in art making with other artists, AI can be considered as co-author.
- We propose an effective way to inject Artificial Imagination into making artworks in the form of Mind Map, which includes considering semantic similarity, integrating informative linguistic features, inheriting author's mind, and inserting Dadaism and impossibility of improvisation principles.
- We situate our work both in arts and Artificial Intelligence, and further develop a set of metrics to evaluate the quality of our proposed methods, which are relevance, linguistic connection, Dadaism, and overall artistic impression.

## **BACKGROUND: ART, TECHNOLOGY, AND MIND MAP**

### **Technology in Arts**

Artists have a long tradition of embracing new technology in their practice. With so much have accomplished, recently artists have been expanding their great vision, to cultivate a more and more diverse and electrified arena in the AI-enabled creation. With the AI technology, the artists are able to dream about the endless possibilities of art creation in the future.

In the Renaissance, there has been overwhelmingly scholarship on correlations of understanding human body through anatomy and the evolutionary achievements in paintings and sculptures. The art of the Renaissance is less contented in directly imitating the mere appearance of nudes, but cherished with a dedication in anatomical dissection to accurately represent the human body in paintings and sculptures. Their fascination of studying anatomy transcended beyond human body's external visual characteristics to its biological supporting structures.

In modern times, industry revolution paved the way for artists to create with mechanical reproductive methods. Walter Benjamin contrasted artworks of this period and onwards with the ones came earlier and called for a diminish of aura (Walter, 1968), a unique aesthetic authority, in the mechanical reproduced artworks, such as photography. Since then, the appreciation of arts has progressed from the aura to engagement in the social context, from exhibiting in the private room of nobilities to public sphere for a greater number of audiences. In addition, Vilem Flusser wrote intensively on photography, the most popular mechanical reproduction method, that it is not only a reproductive imaging making technology, but a dominant cultural technique through which reality is constituted and understood (Becker, 2012).

With the involvement of new technologies, especially as artists and creators continue to introduce groundbreaking technology into their practice, we can observe a phenomenon that the "author" in artistic creation becomes somewhat ambiguous. The dispersed of authorship unfolds in a sense of the impossibility of improvisation, where variation arises from standardizations.

Improvisation emphasizes an unprepared performances or behaviors. The philosopher Jacques Derrida discussed the act of improvisation in his writing. It needs to be put into the current social and cultural context before it can be interpreted by us. He further explained that we must rely on a set of pre-established models or rules - the system of conventions - to understand improvisation. In other words, the possibility comes from the rules (Derrida, 1989). The creator needs to pre-set a range in which the possibility of improvisation is changed. In order to pursue variations, we must set the rules, then repeat the rules and expect an unexpected outcome.

This framework rooted in arts made our project seem at quite a distance and seemingly unrelated to our immediate research in AI. However, the investigation of AI in art creation more immediately helped to pave the way to a more global perspective because, despite the differences in software and programming, there is a universalizing base to the digital flow. More importantly, we firmly believe, in terms of creativity, technology contributes to art and the vice versa.

## Artistic Mind Map

Mind Map is an index to more information, which leaves traces and provides insights to tangible and flourishing information. It is a system of possibility for knowledge (Philp, 1985). However, we often neglect to confront that the map is mere a reinterpretation of facts, but not facts. When representing the terrain of the mapped object on flat media, there are always gaps between the map and the mapped objects, we compensate that through different mapping techniques by preserving different metric properties. When constructing a mind map, through constantly interpretation and abstraction, naturally it is a process of subject decision making. In addition, Derrida's theory on deconstruction provides us a framework on "how the supposedly literal level is intensively metaphorical (Hoy, 1985)." The cartographic fact becomes metaphor. In this way, viewers are constantly haunted by the facts but never being caught up by the facts. Here, the irresistible tug maps exert on artists arises from the map's mask of neutral objectivity, from its mask of unauthored dispassion (Wood, 2006). In other words, that gap calls for and creates a potential narrative of working with rules, a notion of impossibility of improvisation.

In artworks deriving from maps, artists often weave ideas, individuals, objects, things, and events together, providing audience with the possibility to understand them in relationships. The form of maps can carry multiple functions in artistic practice: it can be self-awareness, framework, exhibition plan, ideological exchange, political topology, but also the vehicle of historical and cultural research. By doing so, artists often break the line cartographers have tried to draw between map as a form of graphic communication and paintings and drawings. However, it is exactly where map arts spark and provide visionary artists electrified arena. By relinking detonation and condonation, it captures the beauty of non-linear but semantic thinking. It is not so much a sorting and classification, but rather a depiction of chaos. During this process, artists have access to and draw from existing facts and relationships among facts, but attentively introduce manipulations to formulate and reconstruct the original tableaux in order to spawn new ones.

In a word, these features of artistic Mind Map, the nature of impossibility of improvisation and the flourishing information connection, provide us lots inspirations on the design of Artificial Imagination methods, which will be shown in the following part.

## RELATED WORK

### Previous Work on AI Painting

Many researches have been completed in AI injected art creation such as poem (Zhang & Lapata, 2014; Cheng et al., 2018), music (Thakkar et al., 2018; Hadjeres et al., 2017) as well as artistic image generation (Xu et al., 2018). Among these studies, the exploration of fine arts painting becomes popular with the development of neural approaches such convolutional networks (CNN) and Generative Adversarial Networks (GAN) (Krizhevsky et al., 2012, Simonyan et al., 2014, Goodfellow et al., 2014).

Recent studies demonstrate the power of neural networks in the challenging problem of image generation of artistic painting. Instead of generating paintings from scratch, most of these proposed methods generate images with style transfer from a standard color photograph into either a western style painting or traditional Chinese ink painting. Gatys introduces *A Neural Algorithm of Artistic Style* to perform image style transfer with CNN (Gatys et al., 2016). With the texture transfer algorithm, natural images are transferred into similar style to *The Starry Night* by Van Gogh or to *The Scream*

by Munch. Moreover, the image-to-image translation methods powered by various GAN structures (Zhu et al., 2017, Yi et al., 2017) enriches the styles transfer of natural images into more number of artists' paintings such as Monet, Gezzanne, Ukiyo-e. Apart from western styles, traditional Chinese ink wash painting also attracts researchers interests with neural approaches (He et al., 2018) or stroke-based rendering methods (Liang, & Jin, 2013).

Many of the researches mentioned above only focus on Western style painting or Chinese ink brush painting, whereas there are few studies on the artistic Mind Map generation. As a special type of artistic work, Mind Map can not only reveal artists' experience and understanding to world connections, but also present their skills to create unique visual experience by composing the connection and semantic meaning of the thinking world. Besides, during artistic work creation, the previous neural approaches mainly rely on model performance. Extracting certain patterns or features from different painting style, the images generated from these methods are only an imitation of the original author, which is a pastiche and genre. There are a few studies exploring the interaction between the artists and AI during artistic work creation.

### Previous Work on Imagination

As illustrated in previous section, mind map is a special type of drawing in the field of art. Whereas the essential idea about mind map is the expansion of concepts or ideas concerned within a keyword. Thus, in this research, instead of discussing the drawing techniques of mind map, we pay our attention on the AI imagination for mind map expansion. In the domain of Natural Language Processing, semantic expansion is realized by calculating semantic similarity between words. Studies on semantic similarity matching or semantic expansion rely on knowledge-based methods or corpus driven approaches (Leacock & Chodorow, 1998; Dong et al., 2010). Knowledge based approaches rely heavily on the existing ontology and usually can't scale up. Corpus-driven methods learn vector space representations for words from text data, which can capture the semantic and syntactic information. Recent studies for learning vector-space representations focuses on the local context information. These methods have succeeded in capturing the semantic and syntactic information for word vector representations (Pennington et al., 2014; Mikolov, 2013).

However, there are still limitations of applying corpus-driven methods into Mind Map creation. The main drawbacks of using word vectors in semantic expansion for art creation is that, these word vectors are learned only within corpora distribution information and are lack of the creative feature. Despite the similar syntactic or semantic information that a word vector can represent, the candidates selected are barely aggregations of discrete vectors. Derivation of the same root, nouns in the same category and words with similar meaning are clustered for the word mapping expansion. Whereas the expanded words can barely satisfy the diverse, creative, and imaginative features for mapping art creation.

## SYSTEM ARCHITECTURE OF MAPPA MUNDI

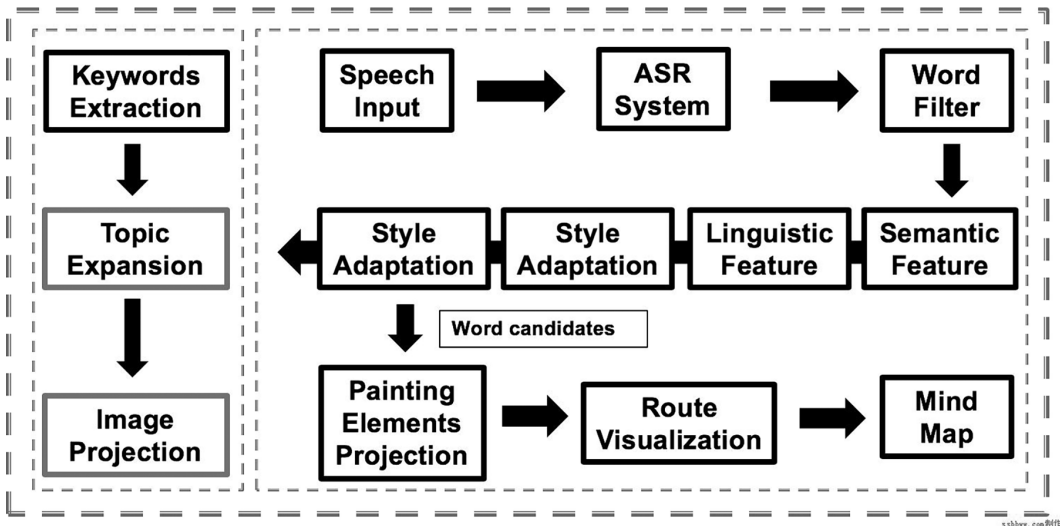
Mappa Mundi system includes four modules: Automatic Speech Recognition (ASR), keywords extraction, topic expansion and image projection module. The detail of Mappa Mundi is illustrated in Figure 2 below.

### Automatic Speech Recognition

Automatic Speech Recognition (ASR) engine is designed for interaction, which converts the voice input into text, as vocal communication is the most natural way for human-machine interaction and may lead to more flourishing thoughts for artist.

We follow the previous works (Cui et al., 2015) of ASR systems with an end-to-end trainable deep learning approaches over sequences of signals as input and recognized text as output. Compared with previous ASR pipelines, which consist of various components such as feature extraction, acoustic

Figure 2. System architecture of Mappa Mundi



model and language model, the End-to-End (E2E) system with neural approaches enables the realization of speech recognition within a single model. Moreover, it's function to process different languages such as Mandarin Chinese and English with a little modification.

The architecture of E2E ASR (Chorowski et al., 2015; Cui et al., 2015) system includes an encoder, which encodes a sequence of acoustic frame of input into a sequence of hidden representation, and a decoder, that produces the output text with the previous timestep prediction and current input character. An attention mechanism is also applied in the system, and it allow the encoder to focus on certain part of the input during decoding. We use a bi-directional LSTM model as encoder and content-based attention mechanism mentioned in (Luong, Pham& Manning, 2015). While the LSTM based decoder takes input of the last hidden state of encoder concatenated with the context vector learned from attention layer. Moreover, a Language Model (LM) method is also applied during decoding. The LM score are integrated into character prediction during each timestep. The use of language model helps to integrate more linguistic information from a great amount of external unlabeled text. Finally, the ASR model is trained with the Connectionist Temporal Classification (CTC) loss function (Graves et al., 2006).

During training, we use around 2000 hours dataset for Mandarin Chinese and around 300 hours for English. To ensure the performance of ASR system in art domain, we prepared around 300,000 vocabularies that can be included in Mind Map creation and their relevant text. Moreover, we adopt the language model with this domain-specific dataset.

### Information Extraction

The ASR system will convert sequence of voice input into text. As the converted text is continuous, it leads to challenging word expansions if all the words are taken into consideration. In that case, we developed a keyword extraction function to extract meaningful words from the converted text for further expansion.

To exclude less meaningful words from the converted text, we firstly build a Part-of-Speech (POS) tagging classifier, as we believe that, words with specific POS taggers, such as nouns contain more semantic information. We adopted open-source software Jieba for Chinese POS tagging, which utilize Hidden-Markov Model with Viterbi algorithm. As for English, we employ the Stanford parser

for POS tagging. Different from Jieba, Stanford POS parser adopt the maximum entropy approaches for POS classification (Toutanova & Manning, 2000).

Once the words in the input sentence are parsed, only nouns, verbs and adjectives are selected for further filtering, as those categories represents are more informative than categories such as adjectives, pronouns and articles.

To further filter meaningful information, we also build an off-line TFIDF dictionary. We defined the vocabulary by the most frequently used 300,000 words of a 10 million sentences text. Taking each sentence as a document, we calculated the term frequency and the inverse document frequency score for each word in the vocabulary. Once the input text is filtered by POS tagging, we sort the qualified words by their TFIDF scores and only the firstly two or three words in one sentence are kept for keyword expansion.

## Topic Expansion

How to build the connection of given keyword with various candidates is the dominant task in Mind Map generation. In our system, we have explored several features to increase information variety for keyword expansion. The firstly method we have employed is semantic similarity matching based one words vector space representations. Apart from that, we also integrate linguistic features such as morphological and phonological information into consideration. As an artistic style Mind Map, how to integrate artists' experience and understanding of the world into the words connections is one of its unique features. Bearing this in mind, we propose a Knowledge Graph (KG) based method to extract the words and their connections from artist's original masterpieces. Once a target word is included in the KG, its relations are then inherited for the system. Further, Mappa Mundi breaks the restriction of domains and conventions and explores more possibilities for words' connections by creating rules following the famous Dadaism principle in art movement. Finally, with all above mentioned methods, Mappa Mundi can create a branch of creative and informative word candidates for a given keyword. As artificial imagination is the main focus in this paper, we will introduce the detailed methods and their impacts for Mind Map generation in the following sections.

## Image Projection

To visualizes the abstract concepts, Mappa Mundi includes around 3000 pictorial elements which are extracted from the representative Mind Map paintings of Qiu Zhijie, an influential artist in the global. These elements are then converted and to enhanced to a more traditional Chinese Shan-Shui (Mountain-river) painting style. We then categorize them into 5 typical Shan-Shui painting categories including: Architecture, Mountain, River, Tree and Lake. There are a few subcategories in each above to diversify overall image visual appearance. To project each word representation of Mind Map into visualized elements, Mappa Mundi classifies each word into one of the 6 given categories and then connect it with the pictorial elements in that domain. Moreover, an additional type of painting element Route is illustrated to connect other pictorial elements. The length of the Route, the distance of the keyword and its candidate is calculated with their similarity score and then connects with Route in Mind Map image. The more similar the two words is; the closer the distance is when projected in Mappa Mundi.

With integration of artistic imagery, we want to show what drive researchers both in the art and AI community ambitious answers to this question: expansive learning, as well as our urge to deconstruct and reassemble ideas for further consideration and discussion. Here, we use the pictorial conventions of cartography and landscape painting to chart geographies that encompass history and philosophy, art and AI.

## PROPOSED METHODS FOR ARTIFICIAL IMAGINATION

In this research, we aim to develop Mappa Mundi which can expand word based on semantic meanings, but also reflect the creative and imaginative nature of art work. The corpus-driven semantic expansion mentioned in previous part is the basic source for Mappa Mundi. To increase the diversity and creativity, we firstly consider informative linguistic features, then learn and inherit artist's original mind and style, and finally bring Dadaism into the process. We will show that the proposed methods can increase imagination of AI painting significantly.

### Integrate Informative Linguistic Features

Previous studies show that linguistic feature is very important in children's language acquisition and is also the intrinsic connection of words. According to (Hockett & Hockett, 1960) there are five designed features of language: arbitrariness, duality, creativity or productivity, displacement and cultural transmission, where duality refers to two levels of language structure (primary level for meaningful word units and the secondary level for meaningless sounds). This reveals that lexical and phonetic features contribute to the diverse meaning expression for language.

To address linguistic features in Mind Map, we adopt the morphological and phonological information into word expansion. We propose a rule-based method of examining words that share similar characters or homophonous syllables of seed word. As Chinese is rich in ambiguous words, its characters or words are full of connotations and associations. Exploring the polysemy possibility of Chinese characters/words with the lexical items will also extend the semantic diversity for the seed word and can bring unexpected imagination. Moreover, due to the limited phonetic inventory, Chinese has a significant number of homophonic syllables or words, which are frequently used in Chinese poetry or puns. The investigation of phonetic information in seed word expansion will jump the traditional semantic boundary in Mind Map.

For lexical features, we adopt the longest sub-common string to examine the candidate Chinese words for the seed word. While for phonological information, we firstly convert each seed word into its phonetic representation and then go through the vocabulary to find the words sharing the same phonetic syllable.

### Learn and Inherit Artist's Mind

During creating artworks, both eastern and western thinkers have both vastly invested in the importance of imitation. In history, the Chinese painterly tradition of imitation (Xie, n.d.) shares the similar notion. The Shan-Shui painter repeatedly imitated the painting of the genre before them which eventually introduced subtle variations and led to progress in the large time scale. Based on spiritual reflections of ideas, artists form their own distinct imaginative minds imperceptibly. Therefore, to improve the imagination of AI Mind Map generation, we propose a mind adaptation method that takes artist's paintings as the source of creative inspiration to produce specific artworks.

Specifically, we develop a knowledge graph to imitate and reproduce respective artist's creative and imaginative work. Consisting of words and relations among them, the tree structure graph treats words as vertexes and relations as edges. Note that relations are either hyponym or hypernym in this structure. To construct the knowledge graph, firstly, we obtain inherent and representative words extracted directly from artist's creations. Secondly, according to instructions from these words, we define some topic words that are most relevant to primitive words and prepare further expansion. Finally, based on the artist's understanding of certain topics and domains, we convert seemingly disorder imagination of artists into ordered word expansion rules. What's more, we construct relations between words to imitate thinking procedures of artists. The reason why we employ the non-linear thinking of the artist is because these features can imitate human creation and imagination to the utmost extent.



## Integrate Dadaism Principle

When representing the terrain of the mapped object on flat media, there are always gaps between linked objects shown in map. Cartographers try to compensate those inaccuracies via different mapping techniques by preserving different metric properties. However, artists often break the lines between the objects shown in a map, which offers an alternative for artists when creating and understanding maps of all kind. They pay less attention in following the convention and making the map accurately, but plant the seed of free play of imaginations in those gaps. In that case, an outstanding feature for Mind Map development is breaking rules of convention and exploring possibilities for unexpected connections between ontologies.

In order to integrate these features into Artificial Imagination, we seek to follow above theories in artwork creation. Dadaism is an important art movement in history which rejects the logic, reason, and encourages to express irrationality and anti-bourgeois in the art work. One of the most typical Dadaist works from Marcel Duchamp is the Fountain, in which he broke the semantic boundary between plumbing and fountain and offered a surprising metaphor. Following the internal feature of Dada Poem Generator and Dadaist artworks, we have developed three principles for seed word expansion in Mind Map (although the only rule for Dada is Never follow any known rules):

- Jumping the domain boundaries for word expansion by exploring cross-domain vocabularies;
- Enriching semantic diversities by exploring different part-of-speech tagging words from seed word;
- Breaking the linguistic restrictions by investigating random candidates beyond semantic, lexical or phonetic connections.

## EXPERIMENT

### Baseline Method

In this experiment, we will use semantic similar based methods as the baseline methods for semantic word expansion. The words cosine similarities are calculated based on the vector space representations (Pennington et al., 2014, Mikolov, 2013).

### Experiment Setup

Instead of training our own word embedding from large corpus, we use the open resource word embedding for Chinese words and phrases (Song et al., 2018). The available corpus provides 200-dimension vectors representations and covers 8 million Chinese words and phrases<sup>3</sup>. The baseline methods for semantic word expansion is based on word vectors and calculated with cosine similarity.

To facilitate the development of Mind Map, we collect ten Mind Map artworks from one of the famous artists in this field (the same artist from whom we extract the painting elements). Each of the selected map is created within a certain domain or topic, including food, occupations, clothes, AI, body, stories and fairy tales, sports, spiritual feelings and religious etc.

We then extracted around 5,000 unique words or expressions from these maps. We filtered the irregular expression for those more than eight Chinese characters and those cannot be found in the word embeddings. Later we took these words as seed word, and extended the number into around 300,000 candidates with the cosine similarity method. To maintain the high quality of word expansion, we also invited ten university students majored in Experimental Art to manually examine these words and filter the irrelevant ones for certain domains. After manual examination, around 15,500 words are used for candidates in Mind Map generation.

Moreover, with the additional knowledge expansion provided by the artist, we created a knowledge network including 1754 relations and 12,000 entities. This knowledge network is later integrated into Mind Map development as mentioned in previous section.

For human evaluation, we extracted 130 words from the corpus and then extend them with baseline and the proposed methods. For each seed word, we remain at most 7 candidates for comparison and further analysis.

## Evaluation Metrics

The evaluation of extended words or expressions is generally a challenging task and there are no established metrics in previous works, not mentioning the words generated for artwork creation. To better address the performance of the proposed method, we conduct extensive studies in three ways: manual evaluation, quantitative analysis and qualitative analysis methods.

We invited 8 experts to participate in the experiment for human evaluation, who have rich experience for art creation. We also design four metrics for human evaluation as follows:

**Relevance:** it measures whether the expanded words are related to the seed word. Words that are more similar to the seed word will gain higher scores.

- **Linguistics Connection:** it reflects the lexical and phonological information of words when compared with the seed word. For words in the same sub-common string or sharing more similar phonetic syllable with the seed word, they gain a higher score;
- **Dadaism:** it represents a criterion for Dadaism of the expansion results. The stronger Dadaism words have, the higher score they obtain;
- **Overall Impression:** it reflects the general impression, creativity and imagination of words. A higher score means that it leaves a more striking impression on the viewers.

In addition to human evaluation, we also invite three of the experts to manually annotate the method used for each word generation and accepted their annotation when two or more people share the same opinion. In total, four types of expansion method are involved: 1) semantic similarity, 2) linguistic feature, 3) author style and 4) Dadaist method. The detail analysis on distribution of used methods are demonstrated in the section below.

## Qualitatively Analysis

We firstly compared the percentage of different types of word expansion between baseline and proposed approach. To calculate this, we classify each extended word candidate into 4 categories. Semantic Similarity means the candidate word is from word vector similarity. Linguistic Feature means it is expanded based on either lexical or phonetic rule. Dadaism represents the word is generated based on Dadaism principle. And Author Style means the word exists in artist's original artworks. As shown in Table 1, our proposed method

outperforms baseline in measurements including Linguistic information, Dada and Author mind. For the latter two criteria, our method obtains far more distributions of words than baseline, which denotes that the proposed method could generate more unexpected (Dadaism) and specific stylized (Author mind) words.

Higher distribution in Semantic similarity is because all of candidate words in baseline are extended based on word vectors, while proposed method has more expansion options. Furthermore, word vectors can also catch linguistic features sometimes, that's why percentages of Linguistic feature are very close between baseline and proposed approach.

## Human Evaluation Results

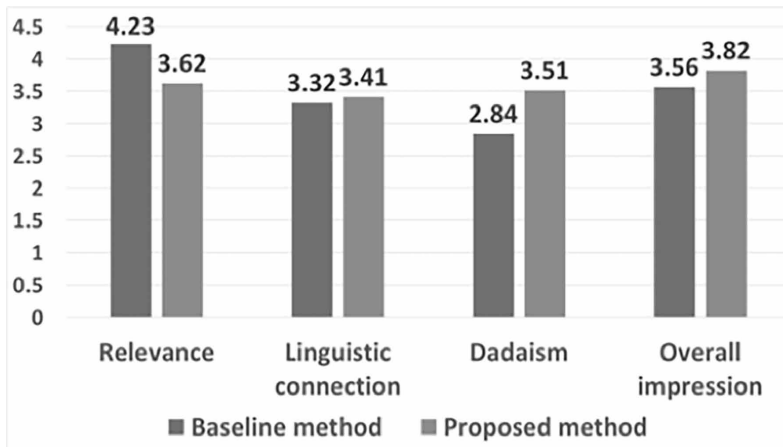
The comparison of human evaluation results is shown in Figure 3. It indicates the average score on the four criteria mentioned in previous subsection. The proposed method outperforms the baseline in the three metrics including Linguistic Connection, Dadaism and Overall Impression. As observed from the first criteria of semantic relevance, the baseline method gets higher score than the proposed

Table 1. Word expansion distributions

	Semantic Similarity	Linguistic Feature	Dadaism	Author Style
Baseline	67.36%	25.82%	4.40%	2.42%
Proposed Method	35.16%	26.37%	22.86%	15.61%

Note that baseline method gains higher distribution of words in Semantic similarity and basically the same percentage in Linguistic feature.

Figure 3. Human evaluation results



methods. This is because only semantic similarities are concerned in baseline. For the second criteria, we observe that, the experts have a little bit higher preference on the informative linguistic features involved in word expansion by the proposed methods. However, for Dadaism, the proposed methods generated many more unexpected and imaginative candidate words. Finally, the linguistic informative features and Dadaism from the proposed methods contribute together to the overall expression of Mind Map generation, which won expert’s preference for the overall impression.

### Case Analysis and Discussion

Table 2 shows the examples of words generated from the baseline method and the proposed method given the same seed word. In general, our proposed methods cover all kinds of expansion strategies and more imaginative.

In the baseline model, Wild Swan, a famous fairy tale of Andersen, is expanded to six words: A fairy tale; Andersen’s fairy tale, Swan, Thumbelina, Swan Princess, and Willow wood Wind, which they are all closely connected to fairy tale, Willow wood Wind is clearly referencing British writer Kenneth Grahame’s The Wind in the Willows. In fact, Grahame’s fairy tale is translated as “柳林风声” shown in the table. Whereas for the results generated from Mundi Mappa, we can see that Madness is extended from Wild swan, however, it is hard to find explicit relationship between these two words. But when these two words are connected together, it describes a picture of how the elegant swan are disturbed by hunters and fly away in a mad way. So, this is the result of considering Dadaism.

In Hypnotherapy, the six expanded words from baseline model entirely derived from medical therapy, or somewhat distant psychoanalysis. It is far more intriguing what our proposed methods provides. Panic Disorder can be treated medically by Hypnotherapy, however, for some people, Hypnotherapy sounds scary or panic (Chinese word “惊恐” can either be translated as scary or panic.). Another expanded word “千与千寻” (Spirited Away) is a Japanese animated film of the lead

Table 2. Examples of word expansion from baseline and proposed methods

Keyword	Words extended from baseline	Words extended from proposed methods
野天鹅 Wild swan	一篇童话 (A fairy tale), 安徒生童话 (Andersen's fairy tale), 天鹅 (Swan), 拇指姑娘 (Thumbelina), 天鹅公主 (Swan Princess), 柳林风声 (Willow wood Wind)	柳林风声 (Willow wood wind), 疯癫 (Madness), 极乐鸟 (Bird of paradise), 琵嘴鸭 (Pick bill duck), 野生大象 (Wild elephant), 拇指姑娘 (Thumbelina)
医院 Hospital	急诊 (Emergency), 手术 (Surgery), 医生 (Doctors), 病人 (Patients), 护士 (Nurses), 放疗 (Radiotherapy), 诊所 (Clinics), 放化疗 (Radio Therapy and Chemotherapy)	疯人院 (Crazy Home), 诊所 (Clinic), 监狱 (Prison), 疗养院 (Sanatorium), 海绵宝宝 (SpongeBob), 住院 (Hospitalization), 毅力 (Perseverance), 手术 (Surgery)
催眠疗法 Hypnotherapy	心理治疗 (Psychotherapy), 心理疗法 (Psychotherapy), 认识疗法 (Cognitive Therapy), 行为疗法 (Behavioral Therapy), 精神治疗 (Psychotherapy), 精神分析 (Psychoanalysis)	惊恐障碍 (Panic Disorder), 腹腔镜 (Laparoscopy), 心理医师 (Psychologist), 镇定剂 (Tranquillizer), 行为疗法 (Behavior therapy), 千与千寻 (Spirited away)
保守党 Conservative party	下议院 (House of Commons), 上议院 (House of Lords), 苏格兰议会 (Scottish Parliament), 英国国会 (British Parliament), 反对党领袖 (Opposition Leader), 议会下院 (House of Commons)	杜勒斯机场 (Dulles Airport), 下议院 (House of Commons), 苏格兰议会 (Scottish Parliament), 英国国会 (British Parliament), 五子棋 (Gobang), 保守派 (Conservatives)
指纹学 Fingerprint Science	工具痕迹学 (Instrumental Traceology), 刑事化验 (Criminal Testing), 足迹检验 (Footprint Testing), 足迹学 (Footprint), 文件检验 (Document Testing), 现代遗传学 (Modern Genetics)	布灵尔 (Bringer), 诺斯替教 (Gnosticism), 青鱼 (Blue Fish), 复杂性理论 (Complexity Theory), 刑事化验 (Criminal Test), 脚趾头 (Toes)

character exploring a wonderland, a world ruled by gods, witches, and spirits, and where humans are changed into beasts. Although Hypnotherapy is a carefully planned medical procedure, it often relies alluring the subject to another reality of illusion. Here, the animated film meets with Hypnotherapy poetically. This poetic interpretation is exactly as mentioned in Section II that Kantian's "Free Play of Imagination." As such, here is parallel not only to animated wonderland film and Hypnotherapy, but to the poem of art meets science.

More interesting, for the proposed methods, “监狱” *prison* is extended from “医院” hospital too, which actually inherits from artist's original mind. The artist believes that hospital is prison where patients lose their freedom of health inside. All these examples show that our proposed approach brings more imagination into word expansion.

In addition, the Mind Map images generated from our proposed methods can also increase the diversity of graphics and enrich the aesthetic pleasure for the audience. Figure 4 and Figure 5 are two screenshots of our system with topic of imagination and neural semiotics, respectively. We can see that they are generated with Chinese Shan-Shui painting style, and the original images are in color.

In Figure 4, the keyword for this screenshot Mind Map is imagination. Many of the connected words shown in the picture, such as curiosity, instinct, genius, are expanded according to their semantic similarity with imagination. While words/phrase like Pure land thought, thought preparation are generated according to the similar lexical features they shared with the topic word. In Chinese, all three of the phrases/words refer to the ability to think. Whereas surreal results from the Dadaism principle as it literally has no meaning connection with imagination. The cluster of words related to dice are generated according to the KG from the artist. He thinks that both imagination and dice will bring people unexpected results and just like dice, imagination will be an important part in life as “no game no life.”

Figure 4. Screenshot of generated Mind Map (Input: Imagination)



Figure 5 is a Mind Map related to Neural Semiotics. Many of the words/phrases surround it are sharing similar semantic meanings. For example, both neural semiotics, neuron model and decision tree learning are terms related to AI. Even though Moral philosophy “道德哲学” and evolutionary biology “生物信息学” are not in the field of AI, they are all sharing the same phonological and lexical element “学” with neural semiotics “神经符号学”. Here “学” refers to an academic discipline that is usually involved in higher education. Whereas the branch of words related to wars are expanded by Dadaism. Though there is no semantic connection or linguist similarity between war and neural semiotics, when these words show together, it tells a story of how dangerous it might be if AI is out of control, just like what is described in fiction movies.

From the two screenshots shown in Figure 4 and Figure 5, we believe our program surprisingly paired a lake with the input word imagination, which poetically gives the viewer a sense of thoughts springing out of it. This indicates that by injecting imagination into AI painting, the artistic quality of paintings can be improved too.

## CONCLUSION

In this article, we propose a Mind Map generator, Mappa Mundi, that can inject Artificial Imagination together with human interaction into an artwork. As the frontier work of AI supported imagination exploration, we also propose a novel approach to increase the creativity, linguistic diversity and irregularity in Mind Map creation. By combining semantic similarity, linguistic connection, artist’s original mind and Dadaism, we improve the imagination of AI painting significantly. We also designed four novel evaluation metrics to measure imagination. Experimental results and extensive analysis

Figure 5. Screenshot of generated Mind Map (Input: Neural Semiotics)



show the effectiveness our proposed methods with respect to Artificial Imagination. In the future, we plan to inject imagination into the visualization process of Mind Map creation, and explore more painting categories too. The presentation of Mappa Mundi as well as the AI imagination approaches are presented to understand how AI can aid artistic practice. Its development also indicates AI has more implications in art than a way of artistic creation, and it enriches the possibility of artistic practice.

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