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Report (Final)

Simulating Artificial Creativity with Robotic Metaphor Production through Natural-Language Processing

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Abstract

This paper research into the potential of simulating Creativity using Metaphor Production. Among existing research into Creativity, it seems as if the consensus is that Creativity is needed for Human-Intelligence. Based on this statement, Creativity is useful as it can be used for innovation. This paper finds that it would be useful to simulate Creativity and will specifically do so by simulating Metaphor Production. This paper found that Metaphors do indeed have uses such as explaining novel concepts.

This paper goes through theory behind why Creativity is useful and how to simulate it. In turn, this paper also goes through the theory of why Metaphors are 'creative' and why they are useful. More importantly, this paper then goes through how Metaphors are simulated theoretically.

To simulate Metaphor Production, this paper carries out 2 experiments which include 1) Robotic Metaphor Production based on dataset collected by participants & 2) Emotion-Bot which is basically an improved version of the first experiment.

In this paper, testing is done on Experiment 1 whereas, Experiment 2 will be tested as a further improvement of this paper. Testing is done by comparing the results of Experiment 1 and asking a small sample size of participants to give their answer on whether they agree with the results. Testing is relatively limited, and emphasis is placed on this for further improvements.

Performance-Wise, Experiment 1 performs relatively weak but better than initial expectations. On-Average Experiment 1 has a 46% chance of producing high quality results. Limitations have been identified and are listed in the Further-Improvements section as well.

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Chapter 1

Introduction

1.1 Overview

Artificial Creativity has been a concept that software researchers have been trying to study and replicate for years. It seems that this is the case due to the ‘untapped potential’ that these researchers believe could be used to explain novel concepts in an unpragmatic way. The consensus among researchers of Artificial Creativity is that: if psychology of human thinking could be replicated, then theoretically ‘creative-programs’ could be invented. Hoorn [14] [15] believes that Fixation in knowledge is one of the main reasons that needs to be overcome when attempting to replicate so called ‘Artificial Creativity’. A state of thinking that is not held back by pre-known knowledge and biases is a perfect example of Creativity. This will be the main idea that this paper will base Artificial Creativity on.

Based on the idea stated by Hoorn [15][16], this paper will use Metaphor Production as a Proof of Concept to simulate this definition of Creativity. This paper believes that simulating Metaphor Production is a perfect example, since Metaphors can be used to associate two completely different objects together to explain either a Literal or Figurative concept. To put it simply, it allows us to easily explain novel concepts that wouldn’t really make sense unless shown through Metaphors. As an **explicit disclaimer:** this is **only an experiment to show how creativity is simulated** and is only a **specific scope** among all the other research on how to simulate Artificial Creativity.

To show that Metaphor Production is an example of Artificial Creativity, this paper will first introduce to the reader the theory & psychology that this paper adopts to make a program ‘creative’.

Subsequently, this paper will then introduce the theory behind what makes a ‘good metaphor’ and how this can be linked to creativity.

Finally, this paper will perform two experiments: 1) Robotic Metaphor Production & 2) Implementation of Emotion Bot. This paper will explain the methodology behind how Robotic Metaphor Production works programmatically and in turn, also explain the methodology behind Emotion-Bot which is a more advanced but specific scenario of human-thinking. The main goal is to provide the reader with the perception that most ideas, especially among software engineers, that his/her ideas will always be skewed by pre-known knowledge or biases.

Chapter 2

<u>Background (Motivation)</u>

2.1 Why is Creativity Important?

The consensus among researchers into Artificial-Creativity, like Boden [3], is that: Creativity is important for Human-Intelligence. Although a broad concept, it specifies that problems in general are usually solved with creativity as a contributing factor.

Li et al. [21] emphasized that creative-design is a key factor in bringing about product-innovation. Furthermore, Colton & Wiggins [7] explained that with innovation, it is identified as one of the most successful strategies for profitable growth, growing market share and even survival.

Although just examples from existing research, such reasons clearly signify the importance of creativity in problem-solving.

2.2 Why learn about the Psychology behind Creativity?

Colton & Wiggins [7] explained that Artificial Creativity is a subfield of Artificial Intelligence which overlaps Cognitive Science & other areas. Cognitive Science is essentially the interdisciplinary research of the mind and its processes with input from Computer Science & Psychology in this case. Thus, to simulate Creativity, a good understanding of how creativity works is essential and hence, a good understanding of Cognitive Science/Psychology is needed to simulate Creativity programmatically.

2.3 Psychology behind Creativity

In essence, this paper will align with **the definition** that: **Creativity is when two completely different objects can be associated together to form a concept that makes sense and in turn overcome bias & psychological inerti**a from pre-known knowledge or biases of these two objects.

Li et.al [21] explained that there are two ways in which Creativity can be simulated: **1) Based on Cognitive Psychology** & **2) Based on Inventive Problem Solving.**

If research was to solely be based on Cognitive Psychology, then importance is placed on "thinking out of the box". This pushes creators to think from wholly different perspectives to overcome psychological inertia. In summary, it tries to search for solutions through as much divergent means as possible even to the point of reaching illogical ones. The problem of solely using Cognitive Psychology is that it tends to be unsystematic and inefficient when applied to technology systems because they rely too much on divergent solutions which tend to produce illogical results.

However, if research were to be fully based on Inventive Problem Solving, then focus is placed on evolving principles of technical systems. In essence, this approach forces the creator to use laws and principles to find patterns to a problem, understand the problem, and in turn make the progress towards creation and in turn, innovate to solve the problem. In summary, it uses logic-reasoning and systemic methods. The problem of solely using Inventive Problem Solving is that it emphasizes too much on 'Conventional Thinking'.

According to Sternberg [6], Creativity can be represented by the following equation:

$$\boldsymbol{DC} = \boldsymbol{f}(\boldsymbol{K}, \boldsymbol{I}, \boldsymbol{TS}, \boldsymbol{DM}, \boldsymbol{ST}, \boldsymbol{U})$$

Note: DC: (Design-Creativity), K: (Knowledgebase), TS: (Thinking-Style), DM: (Design-Motivation), ST: (Computer Supporting Tools), U: (Uncertainties)

The equation for Design-Creativity introduced by Sternberg [8] includes variables from both Cognitive Psychology & Inventive Problem Solving, specifically Thinking-Styles. Following this equation of Creativity, both methods stated earlier will be deemed inappropriate since they each approach one end of the extreme either being 'too-creative' or 'being too logical'. By approaching one of the extreme, this nullifies one or more attributes from Sternberg's Theory, and thus affects Creativity.

To put it simply: as knowledge in a 'Conventional-Thinking' mindset increases, Creativity will eventually decrease. However, as knowledge in a 'Creative-Thinking' mindset increases, Creativity increases. This relationship can be shown in Figure 1 below which was referenced from Li et al. [18]

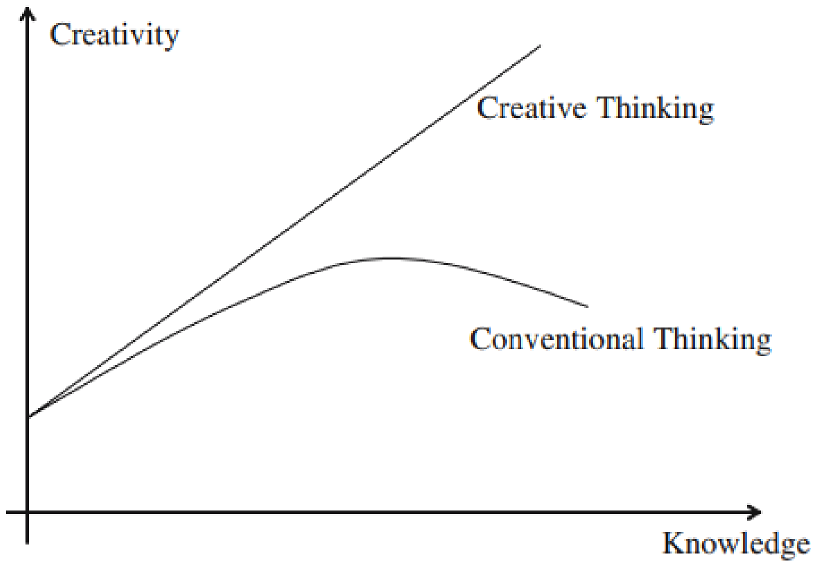

Fig.1 Relationship between Creativity & Knowledge

Sternberg's Theory [8] illustrates that a 'Creative-Thinking' mindset is needed to achieve Creativity. Li et al. [21] emphasized that to do so, balance between 'Cognitive Psychology' & 'Inventive Problem Solving' is needed before designing a Creative-System.

2.4 How to simulate Creativity Programmatically?

As stated earlier, to adopt a 'Creative-Thinking' mindset both 'Cognitive Psychology' & 'Inventive-Problem Solving' needs to be balanced.

This section aims to give a specific description of the strategies that this paper will adopt to simulate the balance between ‘Cognitive Psychology’ & ‘Inventive Problem Solving’ whilst creating the Robotic Metaphor Creation program.

To simulate ‘Cognitive Psychology’, this paper will adopt Form-Oriented Design whilst creating the software.

2.4.1 Form-Oriented Design

Form-Oriented Design is a strategy that utilizes non-logical thinking methods to create novel designs. It does so by associating ideas through Random-Inspiring methods.

2.4.2 Random-Inspiring Methods

Random-Inspiring methods make use of the computer to generate random objects and help creators associate from different points of views. In a sense, it forces the creator to make novel associations, even though they do not make sense.

2.4.3 Balance between Cognitive Psychology & Inventive Problem Solving

The definition of Random-Inspiring Methods may feed more into the extreme of the non-logical aspect of creativity. Thus, it is wise to filter out results that ‘feed into this extreme’. Since this paper is focused on Metaphor Generation, results that do not fit into the Metaphor Category will be considered ‘extreme’ and filtered.

To understand how to filter such extreme results, it is the perfect scenario to understand how Metaphors are produced and in turn apply such conditions programmatically. By applying these conditions, we are in turn using ‘Inventive Problem Solving’ and balancing out the illogical ‘Cognitive Psychology’ aspect of Creativity.

Based on the statements above, this paper believes that Robotic Metaphor Production plays a fine line in balancing Cognitive Psychology & Inventive Problem Solving by combining Random Inspiring Method of associating with the principles of Metaphors. Thus, this paper deems Metaphors as ‘creative’.

The next few sections will give a summary of how Metaphor Production works.

2.5 What is a Metaphor?

According to Hoorn [16][17], **a Metaphor is essentially an Association between two Words from Non-Adjacent Categories.** An example is shown in Figure 2 below, which specifies that the teacher arrives to work early.

The teacher is an early bird.

Fig.2 Example of a Metaphor

2.6 Why are Metaphors Important?

Hoorn [16][17] specifies that there is indeed a bias that Metaphors are 'solely' associated with art. However, existing research provides a different view from such statement. Existing research into Metaphors give a general picture that its theory can be applied to many completely different aspects.

To give a few examples, Black [4] illustrated that Metaphors can be used as a tool to give a better Meaning, Representation, Understanding, Science and Education of Concepts/Ideas. Although, this may be a general abstraction, in summary Metaphors are extremely useful when trying to explain a complex idea to someone unaccustomed.

Miller [11] strongly believes that such an abstraction can be used as a model for scientific thought. Casakin [6] believes that Metaphors play an important role to guide reasoning and enhance innovative thinking. Casakin [6] is confident that metaphors can be employed to assist in identifying and capturing design concepts and define goals and requirements.

Blackwall [5] states that Metaphors are widely used in HCI as a mapping process from a known object to an unfamiliar one. Essentially, Blackwall [5] states that Metaphors can be used in HCI to familiarize a difficult concept through a mapping process.

These are just some examples of the uses of Metaphors when problem solving. Although, it may seem like Metaphors are an omniscient solution to everything in general, this is not the case.

Metaphors do indeed come with its limitations and should not be considered a be-all end-all to explaining concepts. Hoorn [14] states that Metaphors may become obsolete in the following scenarios:

1) Some Concepts are supposed to be viewed Literally & not Metaphoric.

2) Metaphors are not the only way to explain new ideas. Logical Reasoning & Analogical Reasoning could be used instead.

3) Metaphors wear out. Frequent use of Metaphors makes it part of the standard rather than novel.

However, even with such limitations, it still does not hinder the fact that Metaphors are considered 'creative'. The point of this paper, as stated in the introduction, is to simulate Creativity, and Metaphor Production is a clear example of such phenomenon.

2.7 Why are Metaphors considered Creative?

However, even with such limitations, the common consensus is that Metaphors are still considered a 'creative-endeavor'. Based on the previous claim this paper made: '**Creativity is when two completely different objects can be associated together to form a concept that makes sense and in turn overcome bias & psychological inerti**a', this paper believes that Metaphor Production fits such claim.

This paper also believes that Metaphor Production indeed finds a balance between 'Cognitive-Psychology', where two completely different objects are associated together, and 'Inventive-Problem Solving', where rules are applied to create Metaphors.

Since Cognitive Psychology & Inventive-Problem Solving are balanced, this indeed also provides further emphasis that Metaphor Production is considered creative.

In summary, Metaphors affect our reasoning by giving a simple abstraction of complex ideas. Since it fits the criteria previously stated, this paper emphasizes that it is indeed creative.

2.8 How are Metaphors Created?

In simple terms, Metaphors can be considered in an **'A is B'** format or more specifically, **Noun1 is Noun2**. This paper **explicitly defines a Metaphor to be association between Two Nouns**. Hoorn [16] stated that Nouns are **the building blocks used to define a class of ideas.** Thus, this paper believes such association will be sufficient to explain the concept behind such association.

However, such an association needs to be out-of-category for it to be considered a Metaphor. There **are two types of Associations**: **1) Out-of-Category** & **2) In-Category**.

2.8.1 Out-Of-Category vs In-Category

1) **Out-of-Category** means that an association is made between two objects from completely different categories.

Time is money

Fig.3 Example of a Metaphor (Out of Category Association)

2) **In-Category** means that an association is made between two objects from completely different categories.

Rose is Flower

Fig.4 Example of a Literal (In Category Association)

2.8.2 Fuzzy-Matching Sets of Features

Before delving into the theory of how Metaphors are determined, the mechanism to make associations between two objects needs to be understood.

This paper introduces such a mechanism as **Fuzzy Matching Sets of Features** between two words (Nouns) associated.

Words (Nouns) often come with their own properties & relations that define the word. Such properties & relations will be called **'features'** of that word (Noun).

When associating two words (nouns) we can determine whether it is a Metaphor by using Set Theory.

Set Theory is defined as the mathematical theory of well-determined collections. Such collections are called sets of objects, which are features of each word (noun) in this case.

When two words (nouns) are associated together, we need to check for how many features match between these two words (nouns).

Hoorn [16] specifies that if two words share many features that are associated with each other, then these two words are often related in meaning. Furthermore, Moral et al. [11] explains that to identify interpretability of whether the results of Fuzzy Matching logic make sense, it needs to meet a specific number of matching conditions, specifically being features in this case.

Thus, the higher the matching features between two nouns, the greater the likelihood that these two words are associated together.

Moral et al. [11] further states that the Fuzzy Matching logic needs to define a ranking of matching features before selecting a subset of them as a proper result.

Thus, the Fuzzy Matching Sets of Features need to have a threshold of Matching Features to be considered a Metaphor. An example of Fuzzy Matching Sets of Features between two words is shown in Figure 5 below.

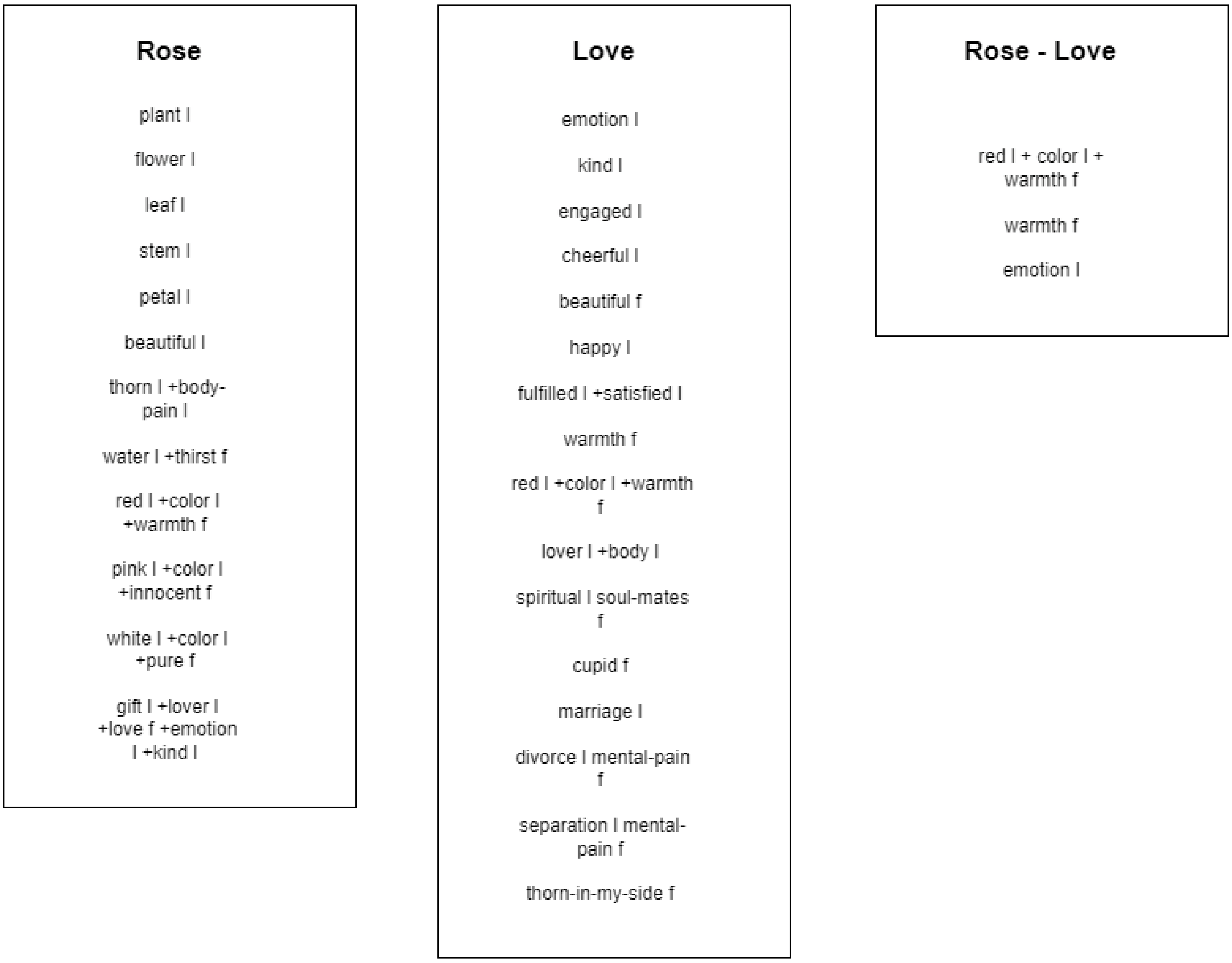

Fig.5 Example of Fuzzy Matching of Features between Two Nouns of Different Categories.

Fuzzy Matching Sets explain how two words (nouns) are associated together. The greater the number of matching features, the higher the likelihood two words are related in meaning. However, this still does not explain how to determine a Metaphor. The section below explains certain thresholds to determine whether an association can be considered a Metaphor.

2.8.3 Metaphors, Literals & Anomalies

Hoorn [17] specifies that there is specific criteria of matching features that Metaphors need to meet. As **an explicit disclaimer, there is no clear 'threshold' on the number of matching features between the two words associated together. Instead, this threshold should be set by the user.** The Metaphor threshold set by the user should be set in a scale between 0 & 1. However, based on the threshold set by the user, there are 3 different results of Associations. The following include:

1) **Metaphor:**
    - **Association denoting an Analogy between two completely different objects.**

2) **Literal:**
    - **Association explaining a literal description of an object.**

3) **Anomaly:**
    - **Association that does not make sense.**

Based on theory in Literature: Metaphors, Literals & Anomalies are sufficient to explain all types of associations between two words. Hoorn [17] carried out experiments to see how to achieve each result and came up with the following conditions based on Fuzzy Matching Sets:

1) **Metaphor Condition:**
    - **Large Intersection between Out of Category Words.**

2) **Literal Condition:**
    - **Large Intersection between In Category Words**

3) **Anomaly Condition:**
    - **Small Intersection between Out of Category Words.**

To give a more in-depth explanation:

1) Metaphors are considered only when the intersection of features between two words is greater than the threshold set by the user. In addition, the association needs to be between two out of category words. Out of Category meaning: two objects of completely different criteria (e.g: Rose [cat > Flower] & Heart [cat > Body], etc).

2) Literals are considered only when the intersection of features is close to identical between two words. In addition, the association needs to be between two words of the same category. In Category meaning: two objects of same criteria (e.g: Rose [cat > Flower] & Flower [cat > Flower], etc)

3) Anomalies are considered only in two cases:

   a. When the intersection of features between two Out of Category words is below the Metaphor threshold set by the user. (e.g: Cat [cat>Animal] & Car [cat>Vehicle])

   b. When the intersection of features matches the Metaphor threshold but is between two In Category words. (e.g: Rose [cat>Flower] & Lily [cat>Flower].

Chapter 3

Related Work

To reiterate, this paper is trying to prove that Artificial Creativity can be simulated through Robotic Metaphor Production. Given the topic, this paper will be related to studies that theorize how to simulate Creativity & why it is so useful. In addition, this paper will be related to literature that define the theory & practical use of Metaphors.

Upon reviewing state-of-the-art literature among this topic, this paper could only find studies that bolster the usefulness of Metaphors for problem solving in general.

However, with regards to Creativity, this paper found that studies for the ‘general usefulness’ of Creativity has been applied to many different problems programmatically.

3.1 Existing Work

This paper found a Concept Generator, Divago [14] that generates new concepts using conceptual blending. It seems that it works similarly to Robotic Metaphor Production, however it only considers very specific concepts and meshes them together to form a novel one.

3.2 Difference from Existing Work

In contrast to Divago, Robotic Metaphor Production works entirely different by considering additional restrictions such as the possibility of 1) Metaphors, 2) Literals & 3) Anomalies. The only similarity is that Divago considers a sub-par version of Fuzzy Matching Sets which only considers a specified goal rather than general matching features. This paper found that Divago & other Conceptual Blending projects is bound to very specific goals which is very different from Robotic Metaphor Production.

3.3 Possible Novelty

It seems though that there is no existing research related to Metaphor Production programmatically. Existing literature for Metaphor Production seems to all be theoretical or tested with real life subjects.

Having said this, this paper states that Creativity is indeed related to Metaphor production. Since this paper stated there is no existing research into Metaphor Production programmatically, this paper believes that there is indeed possible novelty into researching the process of simulating Metaphor Production programmatically. Hence, this paper is combining existing research to investigate a possibly novel concept: Robot Metaphor Production.

Chapter 4

Research Question

As previously stated in the introduction section, this paper will address two questions: ‘Whether Metaphors are considered creative?’ and ‘Whether Robotic Metaphor Production can be simulated programmatically.”

4.1 Whether Metaphors are considered creative?

The first question has been answered in the Background chapter of this paper, and yes, this paper does indeed believe that Metaphors are considered creative. So, this first part of the research question has been answered.

4.2 Whether Robotic Metaphor Production can be simulated programmatically.”

The second question, “Whether Robotic Metaphor Production can be simulated programmatically” will be considered the main Research Question of this paper hereafter.

Theoretically, the implementation of Robotic Metaphor Production can be shown through Fuzzy Matching Feature-sets between two nouns, as stated previously in the Background section.

Programmatically, the implementation of the Fuzzy Matching Feature-Sets can be easily implemented, which will be shown in the Project Methodology section below.

However, a problem with such implementation would be a limited Knowledgebase. Wolff [ ] states that main limitation of Fuzzy Matching Sets for Metaphor Production will be the lack of semantic features of the two words being associated together. Wolff [ ] goes to state that the lack of semantic features would lead to a deadlock in describing the feature equivalence between the two words being associated. Thus, the semantic feature set will have a direct impact on how Robotic Metaphor Production can be simulated.

To address this problem, this paper has decided to perform two proof-of-concept experiments around this problem.

The first experiment will be Robotic Metaphor Production based on pre-defined collection of Words (Nouns) and their corresponding Feature-Sets. The Feature-Sets used in the first experiment were collected from a survey experiment conducted by Hoorn [18] that associated a collection of features with their corresponding words from a sample size of 50 students from an Undergraduate Design class.

The second experiment will be a more advanced version of Robotic Metaphor Production known as Emotion-Bot. As previously stated, Boden [3] states that Creativity is essential for Human Intelligence. Basically, this means if the program was designed with the intent to simulate Creativity & Human-Thinking, then a program has a higher chance of being creative. To do this, steps can be made up the meta-mountain by repeatedly asking, answering, and coding questions that simulate Creativity or Human-Thinking. This phenomenon is known as Climbing the Meta Mountain which was explained by Colton [7]. To simulate Human-Thinking Emotion-Bot will make use of human aspects such as detecting emotion in sentences and automatically finding relations & properties of words. This paper will allow such features by making use of Transformers (BERT) and Conceptnet, a semantic network, used to retrieve relations and properties of words.

The Project Methodology behind both the First Experiment & the Second Experiment will be discussed below.

Chapter 5

Project Methodology

This section shows the implementation of both Experiment 1: Robotic Metaphor Production & Experiment 2: Emotion-Bot.

5.1 Experiment 1 – Robotic Metaphor Production

This section provides an in-depth description of how this paper implements Robotic Metaphor Production.

The Robotic Metaphor Production program was written in Python and makes use of the NLTK (Natural Language Processing Toolkit) toolkit to assist in the methodology. The Sci-Kit library was also used, specifically the Cosine Similarity function.

5.1.1 Assumptions made

The dataset used in this experiment was collected from a survey experiment retrieved from Hoorn's experiment [19]. The features within this collected dataset will be a simple one-word attribute. In addition, the associations made between the two words will always be Nouns. In addition, the Metaphor threshold & Literal threshold (both ranging from 0 to 1) will be determined by the user.

5.1.2 Take User-Input to collect Metaphor Threshold & Literal Threshold

The Robotic Metaphor Production program can only progress when it receives User-Input determining the Metaphor Threshold & Literal Threshold.

Metaphor Threshold: Range from 0 to 1. If the Similarity Score of matching features between two words is above this threshold, then it is considered a Metaphor. However, if it is below then it is considered an Anomaly.

Literal Threshold: Range from 0 to 1. If the Similarity Score of matching features between two words is equal or above this threshold, then it is considered a Literal.

The Robotic Metaphor Production program checks whether both thresholds are floats since they need to be compared to similarity scores in float format.

5.1.3 Read Feature-Sets of Nouns collected by Survey-Experiment

The retrieved Feature-Sets of Nouns collected are collected in an external Text-Document. The Robotic Metaphor Production program was designed to collect such feature sets from Text-Documents in a specific format, shown in Figure 6 below.

Data-Preprocessing is first done to remove trailing & leading spaces from collected features. The data retrieved is then collected and sorted based on what they signify. The main types of data collected includes: 1) Categories & 2) Exemplars (Nouns).

Specifically, the terms as shown in Figure 6 below, mean the following:

- The [catg] term signifies that the word on the left is a Category.
- The [exm > catg] term signifies that the word on the left is an Exemplar (Noun) which is part of the catg Category.
- The words below these terms are considered features.
- If there is an l to the right of the word, it means that it is a literal feature.
- If there is an f to the right of the word, it means that is is a figurative feature.
- If a + sign precedes a word, then it is considered a chained association to the first word in the line.
- The # term signifies that this is the end of the Feature-Set of the noun above.

metaphor_data - Notepad
File Edit Format View Help

@time [catg]

clock l +clock-dial l +clock-hands l

duration l

fast l +quick l

slow l +tardy l

past l +history l

future l

now l

century l +decade l +year l +month l +week l +day l +hour l +minute l +second l

era l +epoch l

long-due l

of-yore l

eternity f

wings f +fly f

#

Fig.6 Example Feature Set of a word collected from a Survey Experiment.

5.1.4 Fuzzy Matching Algorithm w/ Cosine Similarity & Jaccard Similarity.

As stated in the previous sections, Metaphors, Literals & Anomalies are determined based on the amount of fuzzy matching features between two words (nouns).

In this case, the experiment is performed two times through Cosine Similarity & Jaccard Similarity respectively. Both Cosine Similarity & Jaccard Similarity are considered the standard for comparing semantic similarity between two documents. The Cosine Similarity function was referenced from the Sci-Kit Learn library.

Cosine Similarity measures the text-similarity of two documents irrespective of their size. Each word within each document will be considered a vector. With this, the text documents will be in n-dimensional vector space. The Cosine-Similarity of two word-documents is represented as the cosine of the angle between the two n-dimensional vectors, this being the two words associated, projected in n-dimensional space. The Cosine Similarity ranges from 0 to 1. If the score is 1, then the two words are in the same orientation. If the score is close to 0, then the two words have a higher dissimilarity of features.

$$\text{similarity} = \cos(\theta) = \frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\|\|\mathbf{B}\|} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2} \sqrt{\sum_{i=1}^{n} B_i^2}},$$

Fig.7 Cosine Similarity Equation

Jaccard Similarity measures the number of common words that exist between the two documents. Essentially this is just simple Set Theory. Jaccard Similarity is specifically defined as the intersection of common words between two documents divided by the union of those two documents. Basically, the number of intersecting features over the total combined features. If the score is 1, then there is a complete match. If the score is close to 0, then there is high dissimilarity.

$$J(doc_1, doc_2) = \frac{doc_1 \cap doc_2}{doc_1 \cup doc_2}$$

Fig.8 Jaccard Similarity Equation

5.1.5 Loop through all the collected features & fuzzy match each association.

Based on the collected exemplars (nouns) in section 5.1.3, each exemplar within the collection is fuzzy matched with each other. A double for loop is used to loop through each association. With each iteration, both the Cosine Similarity & Jaccard Similarity score is collected. The corresponding features that intersect/match between the two words in the association are also collected. All the necessary collected data is stored in a dictionary. Lastly each association is appended to an empty array, and the result will be an array of associations. The source code for this can be shown in Figure 9 below.

```
# Fuzzy Matching
associations = []

for exemplar1 in exemplars:

    noun1List = []

    for i in range(1, len(exemplar1)):

        if('#' in exemplar1[i]):
            continue

        noun1List.append(exemplar1[i])

```

```
    for exemplar2 in exemplars:

        noun2List = []

        for j in range(1, len(exemplar2)):

            if('#' in exemplar2[j]):
                continue

            noun2List.append(exemplar2[j])


        cosine_similarity_results = tfid_vectorize_cosine(noun1List, noun2List)

        cosine_similarity_score = cosine_similarity_results[0][0][1]
        cosine_features = cosine_similarity_results[1]
        cos_matrix = cosine_similarity_results[2]

        jaccard_similarity_score = jaccard_similarity(noun1List, noun2List)



        # Collect features of Noun1
        feature = noun1List

        if(len(feature) > 2):
            noun1 = dict(exemplar_feature = feature[0], state = feature[1], chained_associations = feature[2: len(feature)-1] )
        else:
            noun1 = dict(exemplar_feature = feature[0], state = feature[1], chained_associations = [] )

        # Collect features of Noun2
        feature = noun2List

        if(len(feature) > 2):
            noun2 = dict(exemplar_feature = feature[0], state = feature[1], chained_associations = feature[2: len(feature)-1] )
        else:
            noun2 = dict(exemplar_feature = feature[0], state = feature[1], chained_associations = [] )


        associations.append(
            dict(
                exemplar1 = noun1,
                exemplar2 = noun2,
                cosine_score = cosine_similarity_score,
                jaccard_score = jaccard_similarity_score,

            ))
```

Fig.9 Fuzzy Match all the collected features.

5.1.6 Perform Heapsort to sort the array of associations based on similarity score.

Heapsort is performed twice, each based on the Cosine-Similarity score & Jaccard Similarity score. This allows for easier processing & easier readability of the results.

5.1.7 Based on Similarity Score & Type of Association, determine whether it is Metaphor.

Final part is to determine whether each association is considered a 1) Metaphor, 2) Literal or 3) Anomaly.

This stage is performed twice, for both Cosine Similarity & Jaccard Similarity respectively.

The program firstly checks whether the association is out of category or in-category.

Given that the association is out of category, If the matching score is between the Metaphor Threshold & Literal Threshold previously set by the user, then it is considered a Metaphor. If the

However, if the association is in-category, yet the similarity score is between the Metaphor Threshold and Literal Threshold, then it will be considered an Anomaly.

If the similarity score is either equal or above the Literal Threshold, then the association is considered a Literal. However, if the similarity score is equal to 1, then it is considered a Tautology (association between exact same words).

If the similarity score is below the Metaphor Threshold, then the association will automatically be considered an anomaly.

5.1.8 List out all the results.

Once all the results are collected, they are all then printed out to show the user.

```
# for Cosine Similarity
heapSortCosine(associations)

print('Metaphor-Threshold:', metaphor_threshold, 'Literal-Threshold', literal_threshold, '\n')

for association in associations:


    exemplar1_noun = association['exemplar1'].split(' ')[0]
    exemplar2_noun = association['exemplar2'].split(' ')[0]

    exemplar1_noun = exemplar1_noun.replace('@', '')
    exemplar2_noun = exemplar2_noun.replace('@', '')

    for category in categories:

        if(category in association['exemplar1']):

            noun1Category = category

        if(category in association['exemplar2']):

            noun2Category = category

    # Print out the Category Associations
    print(association['exemplar1'], 'means', exemplar1_noun,'is an exemplar in', noun1Category)
    print(association['exemplar2'], 'means', exemplar2_noun,'is an exemplar in', noun2Category)

    # Literal when the Similarity of the Association is beyond the Metaphor Threshold
    if(association['cosine_score'] > literal_threshold):
        print(association['exemplar1'], association['exemplar2'],'is Literal')

    # Anomaly is when the Simiilarity of the Association is below the Metaphor Threshold
    elif(association['cosine_score'] < metaphor_threshold):
         print(association['exemplar1'], association['exemplar2'],'is Anomaly')

    # Metaphor must be Out of Category Associations! Meets the Metaphor Threshold
```

```
    elif(noun1Category != noun2Category):
        print(association['exemplar1'], association['exemplar2'],'is Metaphor')

    # Meets the Metaphor Threshold but the Association is In-Category..
    else:
        print(association['exemplar1'], association['exemplar2'],'is Anomaly')

    print(association['cosine_score'])

    if(association['cosine_score'] >= 0.99):
        print('Tautology.')

    #print(association['matching_features'])


    print('\n')
```

Fig.10 Code to determine whether Association is a Metaphor.

5.2 Experiment 2 – Emotion-Bot (extension of Experiment 1)

Emotion Bot is essentially an extension of Experiment 1. It tries to simulate human-thinking by adding two additional features on top of Experiment 1 that being:

- the ability to detect emotion in sentences and
- the inclusion of a semantic network that acts as a brain.

The following sections of 5.2 will address how the 2 additional features above will be implemented.

5.2.1 Enquire User to Input any sentence.

Emotion-Bot requires the user to input any form of sentence. This input will be processed by Emotion-Bot to determine the overall emotion behind the sentence.

5.2.2 Preprocess Input-Sentence of unnecessary words that do not add context then Tokenize.

Emotion-Bot removes unnecessary words from the input sentence such as stopwords, emojis, urls, unnecessary spacing and punctuations, and handles contractions that have the same context. Once preprocessed, the sentence is tokenized and sent to the BERT model.

```python
# Cleans the Text

token_list = []
token_sentence = remove_emojis(token_sentence)
token_sentence = remove_url(token_sentence)
token_sentence = clean_contractions(token_sentence, contraction_mapping)
token_sentence = spacing_punctuation(token_sentence)

words = token_sentence.split()

# Remove Stop Words from Tokenized List (removing words that don't add context)
for word in words:
    if word not in stopWords:
        print(word)
        token_list.append(word)

print(token_list)

token_sentence = " ".join(str(x) for x in token_list)
```

Fig.11 Text-Cleaning applied to User-Input.

5.2.3 Make use of BERT to determine emotion behind the Input-Sentence.

The input sentence is passed through a pre-trained BERT model which determines the overall emotion that is contextualized by the input sentence. The BERT model results in 5 general emotions which include:

1) Love, 2) Joy, 3) Anger, 4) Sadness, 5) Surprise.

Emotion-Bot makes use of transformers (BERT) [1] [2] since it allows for the most optimal performance time-wise when contextualizing a sentence.

Emotion-Bot uses a pre-trained distilled version of BERT, specifically distilbert-base-uncased-emotion, which was created by Bhadresh-Savani which is sourced by Huggingface.

```python
from transformers import pipeline

classifier = pipeline("text-classification",model='bhadresh-savani/distilbert-base-uncased-emotion', return_all_scores=True)
prediction = classifier(token_sentence, )
print(prediction)
```

Fig.12 Distil BERT model contextualizing emotion behind user-input.

5.2.4 Enquire User to Input Second Category to compare the Emotion to.

Emotion-Bot enquires the User to input the Second Category for the association. The Second Category can be anything. The only requirement is that the Second Category must be a Noun. This can be ensured by using the NLTK toolkit to determine whether the user-input is considered a Noun.

5.2.5 Connect to MongoDB & Query Conceptnet to retrieve features of the two cateogries.

Conceptnet [21] is a semantic network designed to help programs understand the meanings & relations of words that people use. Essentially it is a knowledge graph that has common sense knowledge and is popular for Natural Language Processing. Emotion-Bot uses Conceptnet as a sort of a brain to collect all the exemplars of each category.

Emotion-Bot queries Conceptnet to collect exemplars for the Emotion Category, and then queries Conceptnet to collect exemplars for the Second User-Input Category.

All the exemplars of each category will be collected from the words connected to the category through the r/relatedTo [21] relation.

Once done, we have two collections of exemplars, both from Emotion Category & User-Input Category respectively.

```
import re #Regular Expression

conceptnetDB = client["conceptnet"] #ConceptNet DB
edges = conceptnetDB["edges"] # RELATIONSHIPS
nodes = conceptnetDB["nodes"] # EDGES
query_format = "/c/en/"
```

Fig.13 Connecting to MongoDB to query Conceptnet

5.2.6 Once again, query Conceptnet to collect the Features of each of the collected exemplars.

Conceptnet is once again queried through the two collections of exemplars and collects all the related features of each of the exemplars.

Like above, all the features of the collected exemplars will be collected from the r/relatedTo [21] relation connected to each exemplar.

This generates the entire dataset needed for Robotic Metaphor Production.

5.2.7 Based on the two collected feature-sets, perform Experiment-1 for Metaphors.

Then repeat Experiment 1, with the collected feature-sets. This is essentially Experiment 1 but with a much more complex dataset.

5.3 Complete Description of Code.

For the source code of both Robotic Metaphor Production & Emotion-Bot **please look into the listed description in the Supplementary Materials [1] of this paper.**

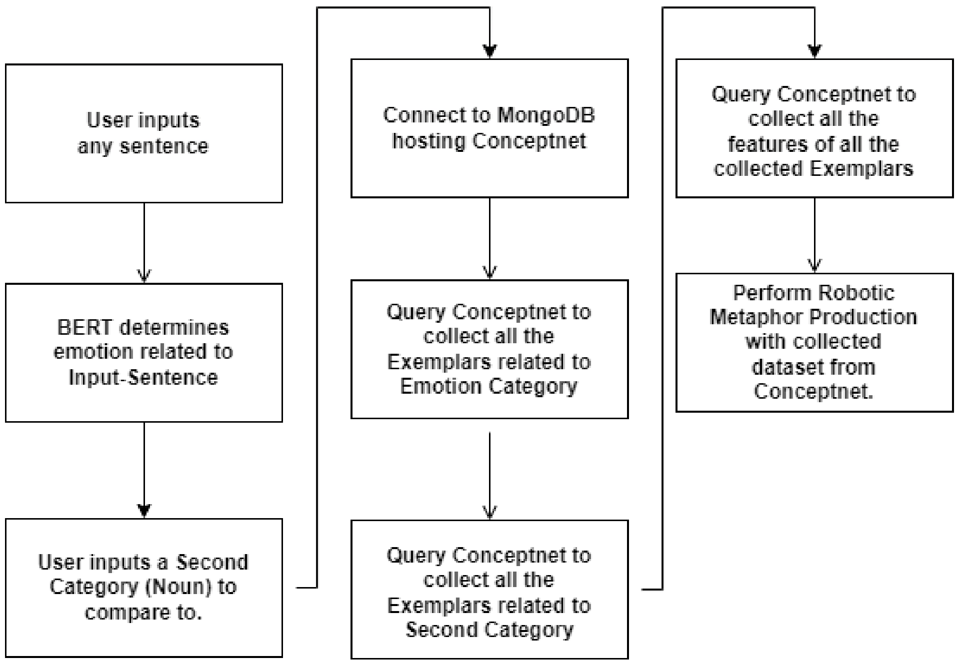

Fig.14 Flowchart of Experiment 2: Extension of Robotic Metaphor Production.

Chapter 6

<u>Results</u>

At this stage, **testing is only done with Experiment 1. Experiment 2 has yet to be tested. However, this paper believes if Experiment 1 can simulate Robotic Metaphor Production, then Experiment 2 should theoretically be worth testing for as it is an extension of Experiment 1**. The results will be based on associations from the collected dataset from Hoorn [19].

6.1 Testing Criteria

The results from Experiment-1 have 4 possible categories: 1) Metaphor, 2) Literal, 3) Anomaly and 4) Tautology.

Since the result of each Association is determined by different individuals, there is the possibility that he/she was able to guess the same result as Experiment-1 results.

To overcome this, a Gambling Threshold of 0.25 is set. This Gambling Threshold is set as 0.25 since the chance of getting the same answer as the Experiment-1 result is 1/4.

Basically, if more than 25% of the sample size got matching results with the test-result then can scoring the result start. Meaning, the evaluation of the quality of result is measured w/ the remaining 75% of the sample size.

The scoring of the quality of each result will be between 1 (being the lowest quality) & 10 (being the highest quality).

The scoring of each result will be determined as so:

Note: N (Sample Size of Test) = 25, **X** = Sample size that matches Experiment 1, **x** = Sample Size that matches Experiment 1 excluding Gambling Threshold

- If Matching-Threshold > 0.25 (Gambling Threshold)
    - Score = ((X – x)/(0.75*N)) * 10
- Else
    - Score = 0

Once the scores of all the test-results have been collected, the average of all the results of each association from Experiment 1 will be taken as the overall quality of the Robotic-Metaphor Production program.

6.2 Participants

The sample size of participants is n=25. The test was conducted among a random select group of individuals through the combination of surveys conducted in real life as well as online surveys.

6.3 Apparatus & Materials

Google Forms was used which shows the results from Experiment 1 including the Cosine-Similarity results & Jaccard-Similarity results. A portion of the test was conducted in person with interview sessions. Interview sessions were conducted with the participant answering either of the four choices: 1) Metaphor, 2) Literal, 3) Anomaly & 4) Tautology.

6.4 Analysis

Based on the Testing-Criteria defined in Section 6.1, Section 6.4.1 & Section 6.4.2 will show the results of Experiment 1 – Robotic Metaphor Production w/ a Metaphor Threshold of 0.2 & Literal-Threshold of 0.9. The results below will also show the results specified by interviewing a small sample size of 25 participants. In addition, the Quality-Score based on the results of the participants compared to the result of the Robotic Metaphor Production program will be stated below. Section 6.4.3 will compare the results of Experiment 1 with Cosine Similarity & Jaccard Similarity respectively.

6.4.1 Experiment 1 Results w/ Cosine Similarity

Metaphor-Threshold: 0.2 Literal-Threshold 0.9

- @yore [exm>time] @love [exm>emotion] is Anomaly
- **Metaphor = 7/25, Literal = 1/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @yore [exm>time] @death [exm>state-of-being] is Anomaly
- **Metaphor = 11/25, Literal = 5/25, Anomaly = 9/25, Tautology = 0/25**
- **Quality-Score = 3/19 * 10**

- @love [exm>emotion] @yore [exm>time] is Anomaly
- **Metaphor = 11/25, Literal = 6/25, Anomaly = 8/25, Tautology = 0/25**

- **Quality-Score = 2/19 * 10**

- @yore [exm>time] @mouth [exm>body] is Anomaly
- **Metaphor = 3/25, Literal = 0/25, Anomaly = 22/25, Tautology = 0/25**
- **Quality-Score = 16/19 * 10**

- @yore [exm>time] @lily [exm>plant] is Anomaly
- **Metaphor = 5/25, Literal = 0/25, Anomaly = 20/25, Tautology = 0/25**
- **Quality-Score = 14/19 * 10**

- @anger [exm>emotion] @yore [exm>time] is Anomaly
- **Metaphor = 7/25, Literal = 6/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @death [exm>state-of-being] @mouth [exm>body] is Anomaly
- **Metaphor = 8/25, Literal = 3/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @lily [exm>plant] @yore [exm>time] is Anomaly
- **Metaphor = 9/25, Literal = 4/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @rose [exm>plant] @yore [exm>time] is Anomaly
- **Metaphor = 6/25, Literal = 3/25, Anomaly = 16/25, Tautology = 0/25**
- **Quality-Score = 10/19 * 10**

- @yore [exm>time] @heart [exm>body] is Anomaly
- **Metaphor = 6/25, Literal = 0/25, Anomaly = 19/25, Tautology = 0/25**
- **Quality-Score = 13/19 * 10**

- @love [exm>emotion] @death [exm>state-of-being] is Anomaly
- **Metaphor = 13/25, Literal = 0/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @yore [exm>time] @anger [exm>emotion] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @mouth [exm>body] @yore [exm>time] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @death [exm>state-of-being] @love [exm>emotion] is Anomaly
- **Metaphor = 16/25, Literal = 2/25, Anomaly = 7/25, Tautology = 0/25**
- **Quality-Score = 1/19 * 10**

- @death [exm>state-of-being] @yore [exm>time] is Anomaly
- **Metaphor = 7/25, Literal = 4/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @heart [exm>body] @yore [exm>time] is Anomaly
- **Metaphor = 3/25, Literal = 1/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @mouth [exm>body] @death [exm>state-of-being] is Anomaly
- **Metaphor = 17/25, Literal = 2/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 0**

- @yore [exm>time] @rose [exm>plant] is Anomaly
- **Metaphor = 4/25, Literal = 3/25, Anomaly = 18/25, Tautology = 0/25**
- **Quality-Score = 12/19 * 10**

- @death [exm>state-of-being] @rose [exm>plant] is Anomaly
- **Metaphor = 22/25, Literal = 0/25, Anomaly = 3/25, Tautology = 0/25**
- **Quality-Score = 0**

- @rose [exm>plant] @death [exm>state-of-being] is Anomaly
- **Metaphor = 14/25, Literal = 0/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @death [exm>state-of-being] @heart [exm>body] is Anomaly
- **Metaphor = 10/25, Literal = 2/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @heart [exm>body] @death [exm>state-of-being] is Anomaly
- **Metaphor = 10/25, Literal = 2/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @death [exm>state-of-being] @anger [exm>emotion] is Anomaly
- **Metaphor = 22/25, Literal = 3/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @anger [exm>emotion] @lily [exm>plant] is Anomaly
- **Metaphor = 4/25, Literal = 0/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @lily [exm>plant] @anger [exm>emotion] is Anomaly
- **Metaphor = 3/25, Literal = 0/25, Anomaly = 22/25, Tautology = 0/25**
- **Quality-Score = 16/19 * 10**

- @anger [exm>emotion] @death [exm>state-of-being] is Anomaly

- **Metaphor = 17/25, Literal = 5/25, Anomaly = 3/25, Tautology = 0/25**
- **Quality-Score = 0**

- @heart [exm>body] @lily [exm>plant] is Anomaly
- **Metaphor = 15/25, Literal = 0/25, Anomaly = 10/25, Tautology = 0/25**
- **Quality-Score = 4/19 * 10**

- @lily [exm>plant] @heart [exm>body] is Anomaly
- **Metaphor = 17/25, Literal = 0/25, Anomaly = 8/25, Tautology = 0/25**
- **Quality-Score = 2/19 * 10**

- @lily [exm>plant] @love [exm>emotion] is Anomaly
- **Metaphor = 17/25, Literal = 2/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>emotion] @lily [exm>plant] is Anomaly
- **Metaphor = 17/25, Literal = 1/25, Anomaly = 7/25, Tautology = 0/25**
- **Quality-Score = 1/19 * 10**

- @lily [exm>plant] @death [exm>state-of-being] is Anomaly
- **Metaphor = 13/25, Literal = 1/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @death [exm>state-of-being] @lily [exm>plant] is Anomaly
- **Metaphor = 12/25, Literal = 1/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @mouth [exm>body] @anger [exm>emotion] is Anomaly
- **Metaphor = 17/25, Literal = 4/25, Anomaly = 4/25, Tautology = 0/25**
- **Quality-Score = 0**

- @anger [exm>emotion] @mouth [exm>body] is Anomaly
- **Metaphor = 4/25, Literal = 11/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @mouth [exm>body] @lily [exm>plant] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @lily [exm>plant] @mouth [exm>body] is Anomaly
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 25/25, Tautology = 0/25**
- **Quality-Score = 19/19 * 10**

- @anger [exm>emotion] @rose [exm>plant] is Anomaly
- **Metaphor = 12/25, Literal = 0/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @rose [exm>plant] @anger [exm>emotion] is Anomaly
- **Metaphor = 4/25, Literal = 0/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @mouth [exm>body] @love [exm>emotion] is Anomaly
- **Metaphor = 12/25, Literal = 0/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @love [exm>emotion] @mouth [exm>body] is Anomaly
- **Metaphor = 12/25, Literal = 0/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @rose [exm>plant] @heart [exm>body] is Anomaly
- **Metaphor = 23/25, Literal = 0/25, Anomaly = 2/25, Tautology = 0/25**
- **Quality-Score = 0**

- @heart [exm>body] @rose [exm>plant] is Anomaly
- **Metaphor = 14/25, Literal = 0/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @love [exm>emotion] @anger [exm>emotion] is Anomaly
- **Metaphor = 9/25, Literal = 2/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @anger [exm>emotion] @love [exm>emotion] is Anomaly
- **Metaphor = 12/25, Literal = 5/25, Anomaly = 8/25, Tautology = 0/25**
- **Quality-Score = 2/19 * 10**

- @heart [exm>body] @love [exm>emotion] is Metaphor
- **Metaphor = 23/25, Literal = 2/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @love [exm>emotion] @heart [exm>body] is Metaphor
- **Metaphor = 24/25, Literal = 1/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 18/19 * 10**

- @heart [exm>body] @mouth [exm>body] is Anomaly
- **Metaphor = 6/25, Literal = 0/25, Anomaly = 19/25, Tautology = 0/25**
- **Quality-Score = 13/19 *10**

- @mouth [exm>body] @heart [exm>body] is Anomaly

- @anger [exm>emotion] @heart [exm>body] is Metaphor
- **Metaphor = 14/25, Literal = 1/25, Anomaly = 10/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @heart [exm>body] @anger [exm>emotion] is Metaphor
- **Metaphor = 19/25, Literal = 0/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 13/19 * 10**

- @mouth [exm>body] @rose [exm>plant] is Metaphor
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 0**

- @rose [exm>plant] @mouth [exm>body] is Metaphor
- **Metaphor = 1/25, Literal = 0/25, Anomaly = 24/25, Tautology = 0/25**
- **Quality-Score = 0**

- @rose [exm>plant] @love [exm>emotion] is Metaphor
- **Metaphor = 17/25, Literal = 8/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>emotion] @rose [exm>plant] is Metaphor
- **Metaphor = 21/25, Literal = 3/25, Anomaly = 1/25, Tautology = 0/25**
- **Quality-Score = 0**

- @lily [exm>plant] @rose [exm>plant] is Anomaly
- **Metaphor = 6/25, Literal = 2/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @rose [exm>plant] @lily [exm>plant] is Anomaly
- **Metaphor = 6/25, Literal = 2/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @lily [exm>plant] @lily [exm>plant] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @death [exm>state-of-being] @death [exm>state-of-being] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @love [exm>emotion] @love [exm>emotion] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @rose [exm>plant] @rose [exm>plant] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @anger [exm>emotion] @anger [exm>emotion] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**

- **Quality-Score = 10**

- @heart [exm>body] @heart [exm>body] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @mouth [exm>body] @mouth [exm>body] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @yore [exm>time] @yore [exm>time] is Tautology.
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

6.4.2 Experiment 1 Results w/ Jaccard Similarity

Metaphor-Threshold: 0.2, Literal-Threshold 0.9

- @death [exm>state-of-being] @mouth [exm>body] is Anomaly
- **Metaphor = 8/25, Literal = 3/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @lily [exm>plant] @heart [exm>body] is Anomaly
- **Metaphor = 17/25, Literal = 0/25, Anomaly = 8/25, Tautology = 0/25**
- **Quality-Score = 2/19 * 10**

- @heart [exm>body] @anger [exm>emotion] is Anomaly
- **Metaphor = 19/25, Literal = 0/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>emotion] @death [exm>state-of-being] is Anomaly
- **Metaphor = 13/25, Literal = 0/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @death [exm>state-of-being] @yore [exm>time] is Anomaly
- **Metaphor = 7/25, Literal = 4/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @death [exm>state-of-being] @heart [exm>body] is Anomaly
- **Metaphor = 10/25, Literal = 2/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @heart [exm>body] @death [exm>state-of-being] is Anomaly
- **Metaphor = 10/25, Literal = 2/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @death [exm>state-of-being] @lily [exm>plant] is Anomaly
- **Metaphor = 12/25, Literal = 1/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @mouth [exm>body] @anger [exm>emotion] is Anomaly
- **Metaphor = 17/25, Literal = 4/25, Anomaly = 4/25, Tautology = 0/25**
- **Quality-Score = 0**

- @yore [exm>time] @mouth [exm>body] is Anomaly
- **Metaphor = 3/25, Literal = 0/25, Anomaly = 22/25, Tautology = 0/25**
- **Quality-Score = 16/19 * 10**

- @anger [exm>emotion] @mouth [exm>body] is Anomaly
- **Metaphor = 4/25, Literal = 11/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @anger [exm>emotion] @death [exm>state-of-being] is Anomaly
- **Metaphor = 17/25, Literal = 5/25, Anomaly = 3/25, Tautology = 0/25**
- **Quality-Score = 0**

- @anger [exm>emotion] @lily [exm>plant] is Anomaly
- **Metaphor = 4/25, Literal = 0/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @yore [exm>time] @death [exm>state-of-being] is Anomaly
- **Metaphor = 11/25, Literal = 5/25, Anomaly = 9/25, Tautology = 0/25**
- **Quality-Score = 3/19 * 10**

- @death [exm>state-of-being] @love [exm>emotion] is Anomaly
- **Metaphor = 16/25, Literal = 2/25, Anomaly = 7/25, Tautology = 0/25**
- **Quality-Score = 1/19 * 10**

- @heart [exm>body] @lily [exm>plant] is Anomaly
- **Metaphor = 15/25, Literal = 0/25, Anomaly = 10/25, Tautology = 0/25**
- **Quality-Score = 4/19 * 10**

- @yore [exm>time] @love [exm>emotion] is Anomaly
- **Metaphor = 7/25, Literal = 1/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @mouth [exm>body] @yore [exm>time] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @love [exm>emotion] @lily [exm>plant] is Anomaly
- **Metaphor = 17/25, Literal = 1/25, Anomaly = 7/25, Tautology = 0/25**
- **Quality-Score = 1/19 * 10**

- @lily [exm>plant] @death [exm>state-of-being] is Anomaly
- **Metaphor = 13/25, Literal = 1/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @lily [exm>plant] @love [exm>emotion] is Anomaly
- **Metaphor = 17/25, Literal = 2/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>emotion] @yore [exm>time] is Anomaly
- **Metaphor = 11/25, Literal = 6/25, Anomaly = 8/25, Tautology = 0/25**
- **Quality-Score = 2/19 * 10**

- @heart [exm>body] @yore [exm>time] is Anomaly
- **Metaphor = 3/25, Literal = 1/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @yore [exm>time] @lily [exm>plant] is Anomaly
- **Metaphor = 5/25, Literal = 0/25, Anomaly = 20/25, Tautology = 0/25**
- **Quality-Score = 14/19 * 10**

- @lily [exm>plant] @yore [exm>time] is Anomaly
- **Metaphor = 9/25, Literal = 4/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @mouth [exm>body] @death [exm>state-of-being] is Anomaly
- **Metaphor = 17/25, Literal = 2/25, Anomaly = 6/25, Tautology = 0/25**
- **Quality-Score = 0**

- @mouth [exm>body] @lily [exm>plant] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @death [exm>state-of-being] @anger [exm>emotion] is Anomaly
- **Metaphor = 22/25, Literal = 3/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @yore [exm>time] @rose [exm>plant] is Anomaly
- **Metaphor = 4/25, Literal = 3/25, Anomaly = 18/25, Tautology = 0/25**
- **Quality-Score = 12/19 * 10**

- @anger [exm>emotion] @heart [exm>body] is Anomaly
- **Metaphor = 14/25, Literal = 1/25, Anomaly = 10/25, Tautology = 0/25**
- **Quality-Score = 4/19 * 10**

- @rose [exm>plant] @yore [exm>time] is Anomaly
- **Metaphor = 6/25, Literal = 3/25, Anomaly = 16/25, Tautology = 0/25**

- **Quality-Score = 10/19 * 10**

- @lily [exm>plant] @mouth [exm>body] is Anomaly
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 25/25, Tautology = 0/25**
- **Quality-Score = 19/19 * 10**

- @anger [exm>emotion] @rose [exm>plant] is Anomaly
- **Metaphor = 12/25, Literal = 0/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @rose [exm>plant] @anger [exm>emotion] is Anomaly
- **Metaphor = 4/25, Literal = 0/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @death [exm>state-of-being] @rose [exm>plant] is Anomaly
- **Metaphor = 22/25, Literal = 0/25, Anomaly = 3/25, Tautology = 0/25**
- **Quality-Score = 0**

- @yore [exm>time] @heart [exm>body] is Anomaly
- **Metaphor = 6/25, Literal = 0/25, Anomaly = 19/25, Tautology = 0/25**
- **Quality-Score = 13/19 * 10**

- @rose [exm>plant] @death [exm>state-of-being] is Anomaly
- **Metaphor = 14/25, Literal = 0/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @anger [exm>emotion] @yore [exm>time] is Anomaly
- **Metaphor = 7/25, Literal = 6/25, Anomaly = 12/25, Tautology = 0/25**
- **Quality-Score = 6/19 * 10**

- @yore [exm>time] @anger [exm>emotion] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @lily [exm>plant] @anger [exm>emotion] is Anomaly
- **Metaphor = 3/25, Literal = 0/25, Anomaly = 22/25, Tautology = 0/25**
- **Quality-Score = 16/19 * 10**

- @rose [exm>plant] @love [exm>emotion] is Anomaly
- **Metaphor = 17/25, Literal = 8/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>plant] @rose [exm>emotion] is Anomaly
- **Metaphor = 21/25, Literal = 3/25, Anomaly = 1/25, Tautology = 0/25**
- **Quality-Score = 0**

- @mouth [exm>body] @love [exm>emotion] is Anomaly
- **Metaphor = 12/25, Literal = 0/25, Anomaly = 13/25, Tautology = 0/25**
- **Quality-Score = 7/19 * 10**

- @love [exm>emotion] @mouth [exm>body] is Anomaly
- **Metaphor = 3/25, Literal = 1/25, Anomaly = 21/25, Tautology = 0/25**
- **Quality-Score = 15/19 * 10**

- @love [exm>emotion] @anger [exm>emotion] is Anomaly
- **Metaphor = 9/25, Literal = 2/25, Anomaly = 14/25, Tautology = 0/25**
- **Quality-Score = 8/19 * 10**

- @anger [exm>emotion] @love [exm>emotion] is Anomaly
- **Metaphor = 12/25, Literal = 5/25, Anomaly = 8/25, Tautology = 0/25**
- **Quality-Score = 2/19 * 10**

- @heart [exm>body] @love [exm>emotion] is Anomaly
- **Metaphor = 23/25, Literal = 2/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @love [exm>emotion] @heart [exm>body] is Anomaly
- **Metaphor = 24/25, Literal = 1/25, Anomaly = 0/25, Tautology = 0/25**
- **Quality-Score = 0**

- @rose [exm>plant] @heart [exm>body] is Anomaly
- **Metaphor = 23/25, Literal = 0/25, Anomaly = 2/25, Tautology = 0/25**
- **Quality-Score = 0**

- @heart [exm>body] @rose [exm>plant] is Anomaly
- **Metaphor = 14/25, Literal = 0/25, Anomaly = 11/25, Tautology = 0/25**
- **Quality-Score = 5/19 * 10**

- @mouth [exm>body] @rose [exm>plant] is Anomaly
- **Metaphor = 2/25, Literal = 0/25, Anomaly = 23/25, Tautology = 0/25**
- **Quality-Score = 17/19 * 10**

- @rose [exm>plant] @mouth [exm>body] is Anomaly
- **Metaphor = 1/25, Literal = 0/25, Anomaly = 24/25, Tautology = 0/25**
- **Quality-Score = 18/19 * 10**

- @heart [exm>body] @mouth [exm>body] is Anomaly
- **Metaphor = 6/25, Literal = 0/25, Anomaly = 19/25, Tautology = 0/25**
- **Quality-Score = 13/19 *10**

- @lily [exm>plant] @rose [exm>plant] is Anomaly
- **Metaphor = 6/25, Literal = 2/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @rose [exm>plant] @lily [exm>plant] is Anomaly
- **Metaphor = 6/25, Literal = 2/25, Anomaly = 17/25, Tautology = 0/25**
- **Quality-Score = 11/19 * 10**

- @heart [exm>body] @heart [exm>body] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @death [exm>state-of-being] @death [exm>state-of-being] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @love [exm>emotion] @love [exm>emotion] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @rose [exm>plant] @rose [exm>plant] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @anger [exm>emotion] @anger [exm>emotion] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**
-
- @mouth [exm>body] @mouth [exm>body] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @lily [exm>plant] @lily [exm>plant] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

- @yore [exm>time] @yore [exm>time] is Tautology
- **Metaphor = 0/25, Literal = 0/25, Anomaly = 0/25, Tautology = 25/25**
- **Quality-Score = 10**

6.4.3 Average Quality-Score

The Quality Score of each result ranges from 0 (Lowest-Quality) to 10 (Highest-Quality).

There are about 64 associations from Experiment 1, so the sum of all the scores will be divided by 64 to receive the Average Quality Score.

6.4.3.1 Average Quality-Score w/ Cosine Similarity

The Average Quality-Score of the associations with **Cosine Similarity is estimated to be around 4.63.**

6.4.3.2 Average Quality-Score w/ Jaccard Similarity

Whereas the Average Quality-Score of the associations with **Jaccard Similarity is estimated to be around 4.55.**

6.4.3.3 Analysis & Limitations of Experiment-1

It seems that the **average performance is similar between Cosine Similarity & Jaccard Similarity.**

However, a significant difference not reflected by the average score was that **Cosine Similarity was able to determine some associations/results to be Metaphors. Whereas, with Jaccard Similarity addressed most of the associations as Anomalies.**

This could be due to limitations in the collected dataset where there is not enough semantical context to produce good results. Thus, why Experiment 2 is carried out with a large semantic network to overcome this problem.

It could also be that Cosine Similarity has a greater ability to contextualize the similarity between two-word documents.

It should also be noted that Experiment 1 was carried out on a Metaphor Threshold of 0.2 & Literal Threshold of 0.9. Different results could be obtained if different thresholds were used.

Although not too different, it seems that it could be concluded that Cosine Similarity in general performs better than Jaccard Similarity. Hence, Fuzzy Matching Sets should be carried out with Cosine Similarity.

Overall performance of the Robotic Metaphor Production program is not too great, only scoring about 46.3% in Quality. However, it scored better than initial expectations.

Chapter 7

Discussion

7.1 Results

Overall, Metaphor Production has enough theory to support its usefulness in innovation. Metaphor Production is indeed ‘creative’ and there is plenty of research signifying that creativity is essential for innovation.

Thus, simulating Metaphor Production should be sufficient in simulating creativity. The overall results of simulating Robotic Metaphor Production, however, did not perform well, with an average performance of 46% in terms of producing quality results. This may be due to the limitations of the dataset & other limitations

7.2 Current limitations

The theory behind Metaphor Production should be sufficient for implementation. There are a couple limitations, however, a main one being the dataset used. The dataset used in Experiment 1 is relatively limited as it only contains a specific number of features collected from individuals.

In addition, there is additional theory given by Hoorn [19] which specifies that features can be divided into Literals and Figurative. Hoorn [19] states that Metaphors are generally produced from associations with large intersection between Literal & Figurative features. This has yet to be implemented in the current version.

7.3 Further Improvements

A further improvement would be to use a larger dataset that covers more features. Therefore Experiment 2: Emotion-Bot was made. It uses a semantic network, Conceptnet to generate a much larger dataset. The larger the dataset the more it simulates a brain. This increases the chance of simulating Human-Thinking and in turn showing good results with Robotic Metaphor P However, analysis has not been done on Emotion-Bot and theoretically it should contribute to such improvement. Further improvement would be to test the results from Emotion-Bot with a relatively large sample size of participants.

Second Improvement would be to apply the additional theory stated by Hoorn [19] which is to include the ability to divide features into Literals & Figurative. With this information it is more likely that Robotic Metaphor Production would be able to determine whether an association is considered a Metaphor.

7.4 Personal Journey

Prior to writing this paper, the author was indeed inexperienced and had little perception of the concept behind Creativity & Robotic Metaphor Production. Whilst conducting research and writing the paper, the author has learnt the importance of looking at things through a broader perspective, whilst not being limited by prior biases. Through this mindset, the author has learnt many new techniques such as simulating theory into code, learning new NLP models & tools, as well as conducting experiments to retrieve statistics. Hopefully as a reader, you will be able to take away from this paper that Creativity is indeed crucial and the way you think is more likely held back by pre known knowledge and biases. Metaphors are a perfect example of such an occasion.

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Supplementary Materials

[1] Source Code for Experiment 1 & Experiment 2: Please view Jupyter Notebook source file zipped in the supplementary folder.