This document is a one page summary of the paper: **Neural Analogical Matching [1].**

I. Problem Statement

An Analogy, is a way to compare two things, and show how one can be defined in terms of another, highlighting their similar characteristics. Humans do something similar in real life, they try to generalise situations over abstract schema to solving new problems based on experience. Hence, Analogy is important to human cognition. On the other hand, there's been a vast research going on to model the human brain using Deep Learning (DL) Algorithms. Therefore, integrating these two areas, has made it to an active area of research in the field of Artificial Intelligence, one step towards a more robust, efficient learning technique as well as modeling human cognition using DL [1].

II. Structure Mapping Theory

Structure mapping theory (or SMT) is one of the oldest and most widely accepted theory of analogical reasoning proposed by Gentner in the year of 1983 [2]. Structure mapping Theory describes that analogy between two domains *(For Example, Hydrogen Atom is Like Solar System")* is the structural alignment of their relations representation or mapping between their relational representations. The mapping between two domains is defined as a triple <M,C,S>. Here M is the set of correspondences between two domains (Nucleus is a corresponds to Sun, or electron corresponds to planets). C is the set of candidate inferences, which can be obtained using the relational representation of the domains by substituting the set correspondences *(For Example, using the relation from Solar System: CAUSES(AND(GREATER(MASS(Sun), MASS(Planet)), ATTRACTS(Planet, Sun)), REVOLVES-AROUND(Planet,Sun)) and M, the candidate inference obtained is: CAUSES(AND(GREATER(MASS(Nucleus), MASS(Electron)), ATTRACTS(Nucleus, Electron)), REVOLVES-AROUND(Electron,Nucleus)))*. Further, S is the structure Evaluation score, which measures the quality of the correspondences.

III. Related Works

Over the time, different cognitive theory for analogical theory have been proposed, but the differences among those makes it a NP-Hard Problem. While some of them don't use explicit graph matching, hence losing the deeply interconnected set of features of the domain. Others have hard-coded matching algorithms, which narrows down their performance differences to only known symbols.

IV. Contributions

- The authors intorduced a neural architecture named as Analogical Matching Network (AMN) that learns to produce analogies between given symbolic representations of two domains.
- It also conforms to the Structure Mapping Theory (SMT).
- AMN doesn't work on hard-coded rules, instead it learns over the training data.

V. Approach and Results

A. Dataset Used

The proposed system uses four datasets, which are mentioned below:

- **Synthetic Dataset:** Generated Examples with the same hyperparameters as the model.
- **Visual Oddity:** Analogy to represent cultural differences using visual geometric representations.
- **Moral Decision Making:** Analogies about moral dilemma.
- **Geometric Analogies:** Contains manually encoded analogies related to geometry.

B. Technical Approach And Results

The Technical Approach consists of a total of four steps, which are as follows:

- The first two steps corresponds to converting the given relational representation into vocabulary independent by randomly substituting the entities, functions and predicates present in the nodes with generic tokens (from a specific set of tokens). One has same substitutions for entities (Label Graph) and the other distinguishes between different entities (Signature Graph).
- The third step is to obtain the output correspondences from the set of unprocessed correspondences (signature graph and label graph as input).
- Further, correspondences along with signature graph is used to obtain the final set of candidate inferences from the set of unprocessed inferences.

The approach uses a categorical cross entropy know as softmax loss as their loss function. It also uses two scoring metrics, Structure Match Scoring (to avoid erroneous correspondences), and Structural Evaluation Maximization (Handle output variability because of random token assignment). **Results:** The system was able to produce mapping scores at 95-104% the level of Structure Mapping Engine (hence conforming to SME). It also obtained high (> 0.9) accuracy , precision, recall, and f1-score over various domains for candidate inference prediction.

VI. Views

- This work provides a major breakthrough by combining the field of Cognition and deep learning, and conforms with one of the most widely accepted theory of analogical reasoning SMT.
- Further, like other analogical computational models, this system can also be used on various applied tasks such as question-answering, machine learning, to test the cognitive theory of human behavior.
- As a part of future work, this can be used to enhance the current state-of-the-art explainable artificial intelligence and deep learning systems.

References

[1] M. Crouse, C. Nakos, I. Abdelaziz, and K. Forbus, "Neural analogical matching," *arXiv preprint arXiv:2004.03573*, 2020.

[2] D. Gentner, "Structure-mapping: A theoretical framework for analogy," *Cognitive science*, vol. 7, no. 2, pp. 155–170, 1983.