Paper Name: Neural Analogical Matching **(AAAI-21)**
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Problem Statement:

- **Analogy is core to human cognition**. It allows to solve problems based on prior experience, governing the way we conceptualize new information and influence perception.
- There's been several approaches to **model human cognition using deep learning** algorithms.
- Hence, **integrating these two lines of research** (Analogy and Deep Learning) is one step ahead towards more robust, efficient learning technique as well as modelling human cognition using DL.

Related Works

- The difference between various proposed theories makes it an provably NP-hard problem.
- Not using 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 to only known symbols.

Contributions:

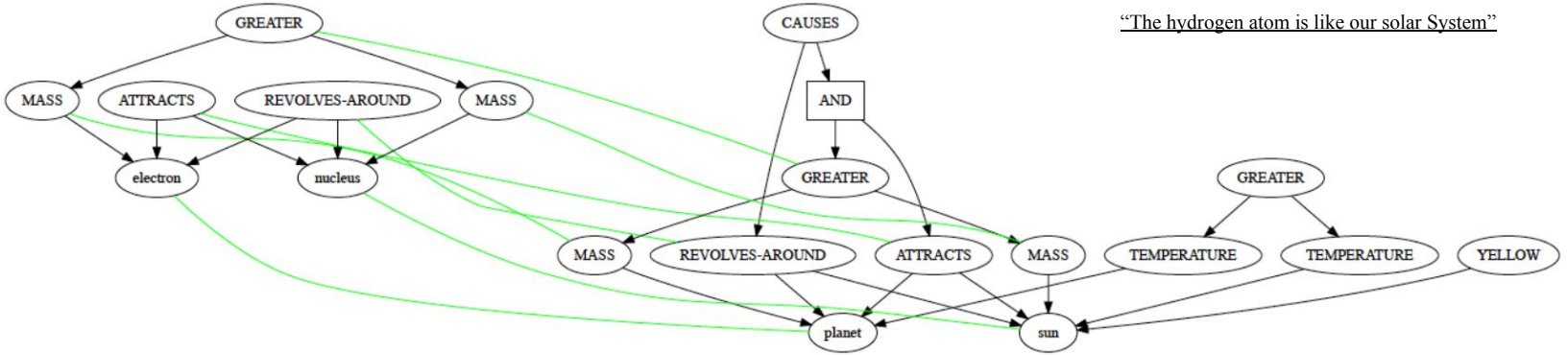
- **Analogical Matching Network (AMN):** A neural architecture that learns to produce analogies between symbolic representations.
  - Symbolic representations: Use of **white colour** is symbolic representation of **something pure, clean, innocent, and peace.**
- A Deep Learning System that conforms to **Structure Mapping Theory (SMT)**
  - **Analogy centers around the structural alignment** (mapping between two relational representations, *Ex: Figure shown below*) of relational representations.
  - **A mapping is a triple <M,C,S>** *(Ex: Solar System and Rutherford Model of atom)*
    - **M -** Set of Correspondences between based and target.
    - **C -** Set of Candidate Inferences
    - **S -** Structural Evaluation Score measuring quality of M.

```
[1]  nucleus
[2]  electron
[3]  MASS([1])
[4]  MASS([2])
[5]  ATTRACTS([1]], [2])
[6]  REVOLVES-AROUND([2], [1])
[7]  GREATER([3], [4])
```

```
[8]  sun
[9]  planet
[10] MASS([8])
[11] MASS([9])
[12] TEMPERATURE([8]])
[13] TEMPERATURE([9]])
[14] REVOLVES-AROUND([9], [8])
[15] GREATER([10], [11])
[16] GREATER([12], [13])
[17] ATTRACTS([9], [8])
[18] CAUSES(AND([15], [17]), [14])
[19] YELLOW([8]])
```

1.M: **<**[1],[8]>, **<**[2],[9]>, **<**[7],[15]>, **<**[3],[10]>, **<**[4],[11]>

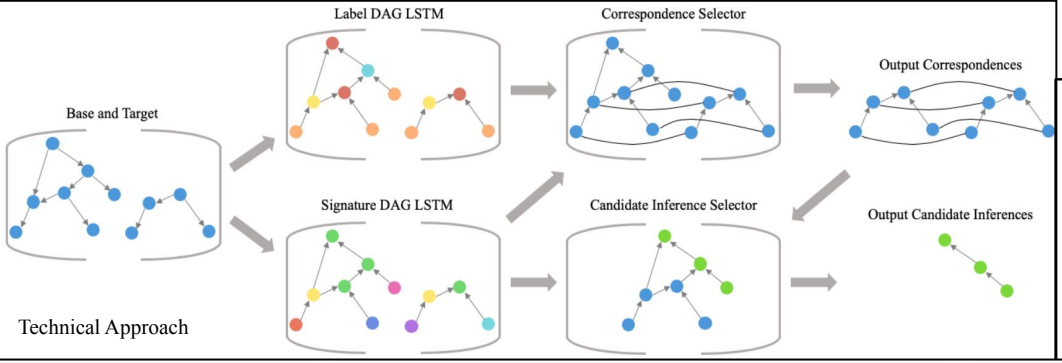
2.C: CAUSES(AND ([7],[5]), [6])



"The hydrogen atom is like our solar System"

Approach: ***(As shown in figure below)***

1. **Dataset Used:** Synthetic, Visual Oddity, Moral Decision Making, Geometric Analogies.
2. **Key Design choice:** Avoid using rules, instead reinforce and learn the output through performance on training data.
3. The base and target domain are considered as **directed-acyclic graph (DAG)**
   a. **DAGs** is a directed graph with no directed cycles. That is, it consists of vertices and edges, with each edge directed from one vertex to another, such that following those directions will never form a closed loop.
4. **Base and Target Graph** are converted into Label and Signature graph. *(Ex: below)*
5. (4) as input in the form of a set of **unprocessed correspondence** to **correspondence selector** to give filtered correspondences as output.
   a. Selector module uses **attention-based transformer.**
   b. 2 layered **feed-forward neural network**.
   c. Further **softmax is used to obtain output correspondence**.



Technical Approach

Approach and Results:

1. (5) and Signature graph is used is given input as **unprocessed candidate inferences to selector module** to obtain filtered output
   a. **Sin and Sout** which are and are not present in the correspondence respectively.
   b. **Compatibility Scores** are passed by **softmax** to obtain **C.**
2. **Loss Function:** Categorical Cross Entropy a.k.a Softmax Loss.
   a. L = Lcorr + λLci
3. **Model Scoring:**
   a. *Structural Match Scoring* to avoid erroneous predictions.
   b. *Structural Evaluation Maximization* to handle variability in terms of output.
4. **Results:** Structure Mapping scores at **(95-104%)** the level of **Structure Mapping Engine (SME)** , hence conforming to SMT.
5. **Results:** High (>0.9) Accuracy, Precision, Recall and F1-Score for prediction of candidate inferences.

My views:

1. This work provides a major breakthrough by combining the field of **human cognition and deep learning**, especially **conforming** with **theory of analogical reasoning**.
2. This system can be further used on **various applied tasks** such as **question-answering, machine reasoning.**
3. As a part of future work for the paper, this work can be used to enhance the current state-of-the-art explainable artificial intelligence, Deep learning systems.

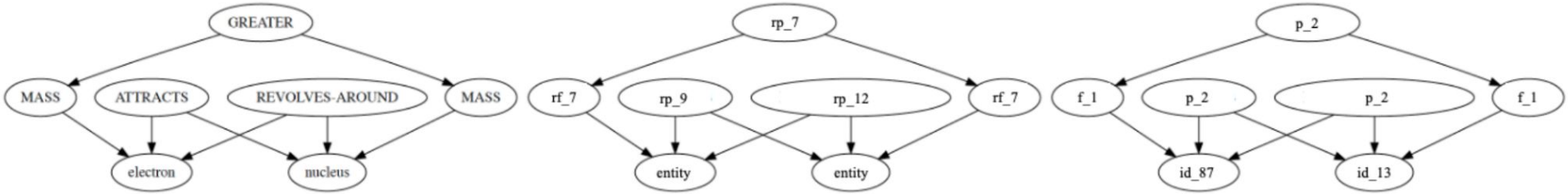


Figure 3: Original graph (left), its label graph (middle), and its signature graph (right)