ABDUCTIVE LEARNING: BRIDGING MACHINE LEARNING AND LOGICAL REASONING

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CONTENT

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PROBLEM STATEMENT

- Integration of Perception and Logical Reasoning
- Challenge of bridging the gap between sub-symbolic perception and symbolic reasoning

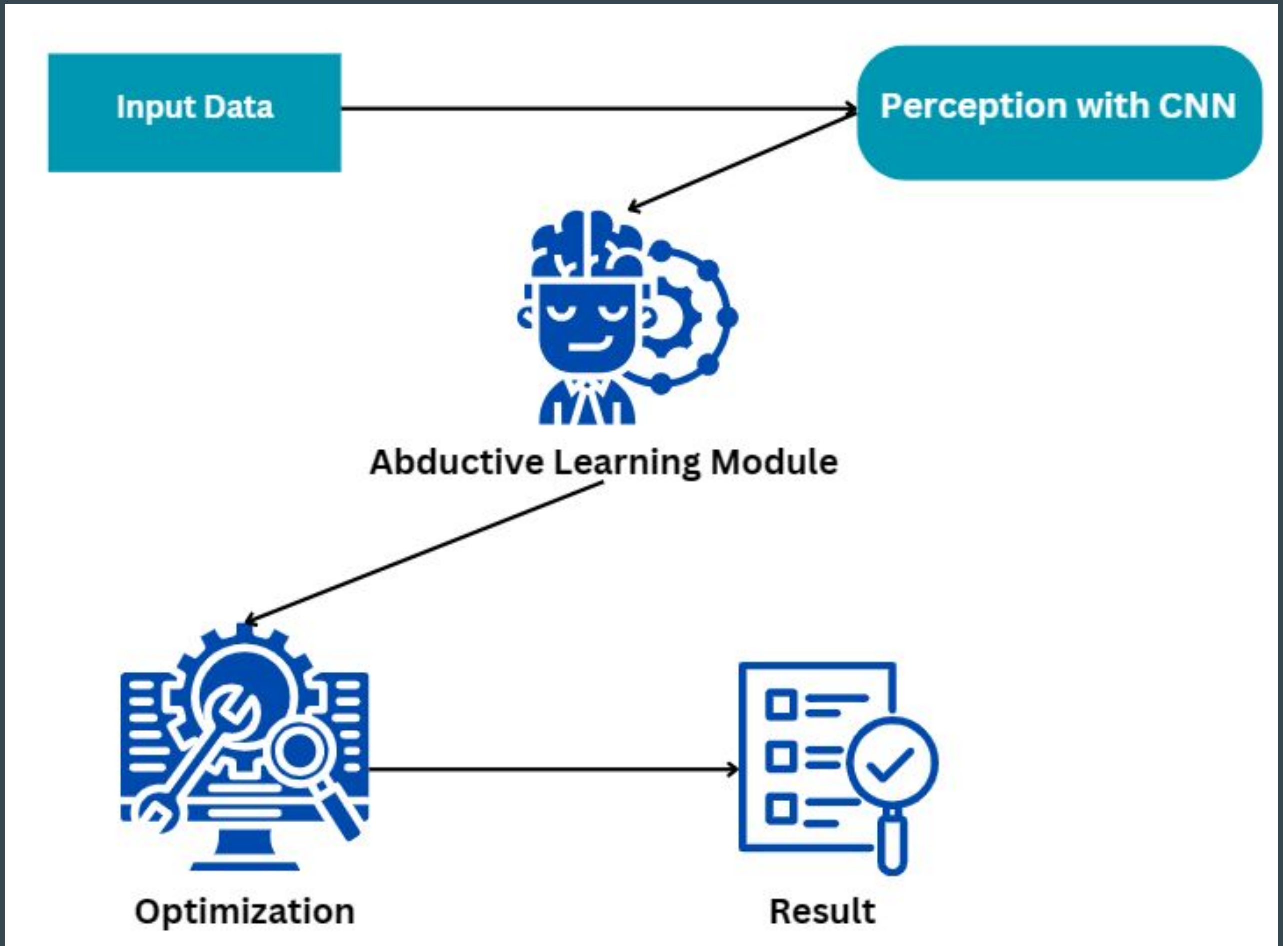
MOTIVATION

- Creating a framework ML can perceive primitive logic from facts
- Developing a ML model to use symbolic reasoning based on domain knowledge base.

DATASET

- MNIST dataset: The MNIST dataset is used to train models for recognising handwritten digits. (example: 1, 0, + and =)

Methodology

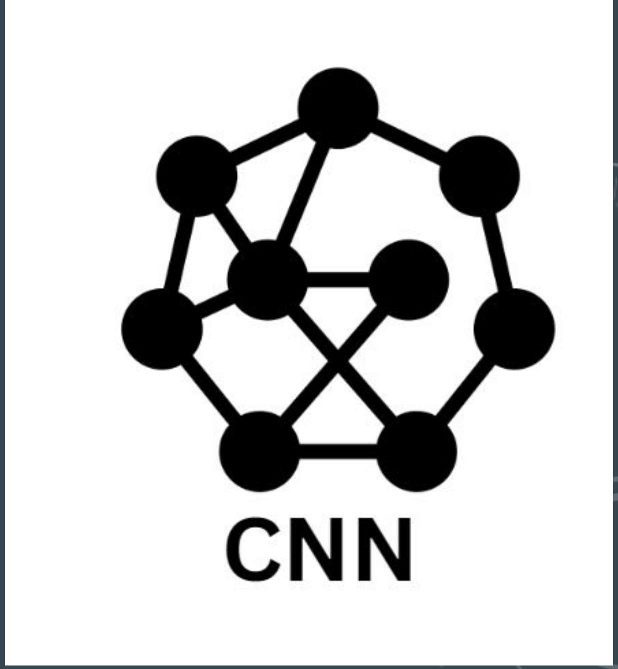


CNN

- The CNN is used for classifying the symbols in the dataset i.e.

- It learns the mapping p: $X \rightarrow P$, which in this case, is a mapping from images to labels in the set {0,1,+,=}.

- The CNN will initially be trained on random labels, which need to be fixed iteratively.



Abductive Learning

- We know the structure of the equation, that is, the digit is a sequence of “0”s and “1”s, and each equation has structure X+Y=Z.

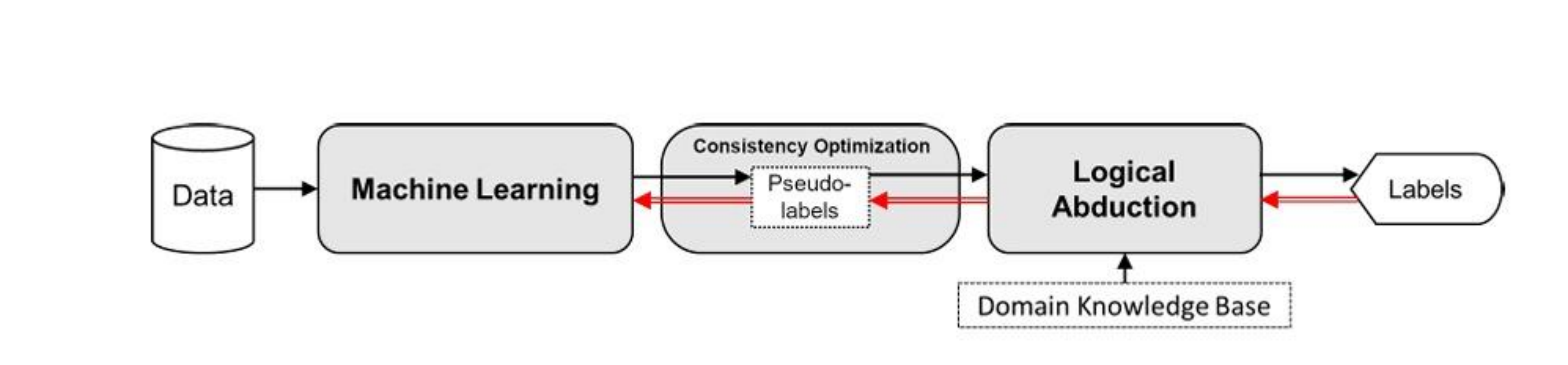
- '+' is known to be a bit-wise operation, and as the digits are binary, '+' could represent any one of the 16 binary operators.

- X, Y and Z have constant length.

Optimization

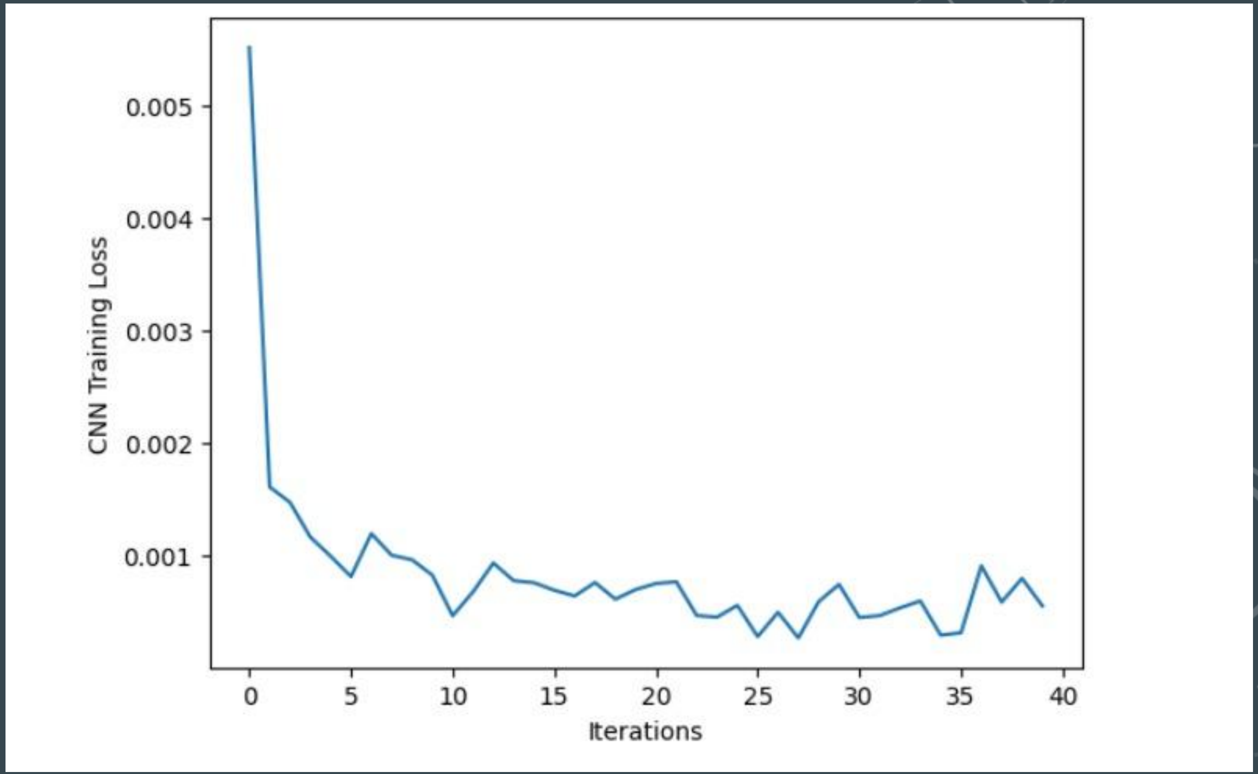
- ABL tries to maximise the consistency between the abducted hypotheses H with training data D, given background knowledge B. It can be defined as:
  - **$Con(H \cup D; B) = \max |D_c|$, where $D_c \subseteq D$**
- Uses greedy optimization

ARCHITECTURE



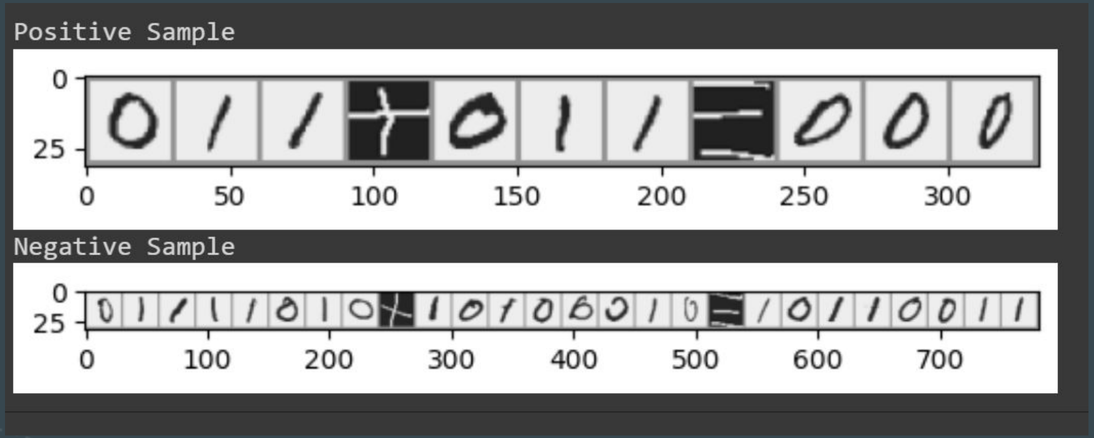
EXPECTED RESULTS

- Initially, learning is rapid and loss rapidly decreases.
- The loss curve fluctuates, notably in the early iterations.
- The loss stabilizes at 0.001-0.002 as the model converges to a stable state.
- No indications of overfitting as loss doesn't significantly increases.
- Indicates that the model is acquiring knowledge efficiently and adapting to training data.



RESULTS

Model training and evaluation with MINST



Consistency score if 'model' is used for perception, given a set of equations and the corresponding labels

Precision	0.994819
Recall	0.898785
Accuracy	0.940909
F1-score	0.944367

RESULTS

Handwritten math equation recognition using Conv2D from keras and solution


```
Symbols:  [8, 5]
Operations:  ['+']
[{'Z': 13}]
```


```
Symbols:  [2, 3]
Operations:  ['*']
[{'Z': 6}]
```

Conclusion

- Implemented the paper
- Bridging the gap between sub-symbolic perception and symbolic reasoning is possible

What we learned from the project?

- Simultaneous enhancement of both perception (comprehending the input data) and reasoning (applying logic/knowledge)
- How machines can perceive primitive facts from learning

REFERENCES

- "Bridging Machine Learning and Logical Reasoning by Abductive Learning" by Wang-Zhou Dai, Qiuling Xu, Yang Yu, Zhi-Hua Zhou.