Sum-Product Network and Its Application to Image Completion

A thesis defense

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Contents

Probability Graphical Model

Importance:

- A rich framework to encode factorization and independence over random variables
- Wide applications: medical diagnosis, image understanding, speech recognition, and natural language processing

Weaknesses of Traditional PGMs

Traditional PGMs:

- Bayesian network
- Markov random field

Weaknesses:

1. Complexity scales unproportionally
2. Approximate learning
3. Intractability
4. Separation of learning and inference

Advantages of SPN

Why SPN:

1. Complexity scales up linearly
2. Exact learning
3. Tractability
4. Combination of learning and inference

What is SPN

Sum-product network(SPN):

- Graph type: DAG
- Leaves: random variables
- Internal node: sum node, product node
- Root: sum node
- Network polynomial: $f_{\mathcal{S}}(\mathbf{X}) = \sum_{X \in \mathbf{X}} \Phi(X) \prod_{X \in \mathbf{X}}(X)$

Example

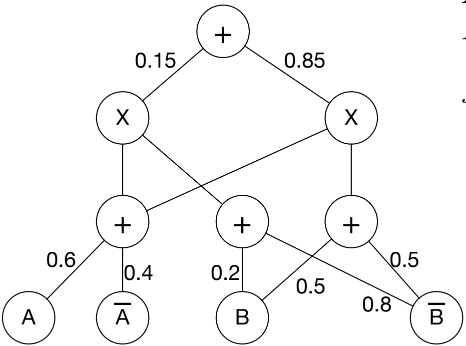


Figure: An Example of SPN

A: Rain $\overline{A}$: No rain
B: Thunder $\overline{B}$: No thunder

$$
\begin{aligned}
&f_{\mathcal{S}}(A, B, \overline{A}, \overline{B})\\
&=0.15(0.6A + 0.4\overline{A})(0.2B + 0.8\overline{B})\\
&+0.85(0.6A + 0.4\overline{A})(0.5B + 0.5\overline{B})\\
&=0.273AB + 0.327A\overline{B} + 0.182\overline{A}B\\
&+0.218\overline{AB}
\end{aligned}
$$

Query: P(rain + thunder) = ?

$$f_{\mathcal{S}}(1, 1, 0, 0) = 0.273$$

Learning Methods

Learning:

- Structure learning:
  - Poon-Domingos Architecture: Rectangle regions
  - Dennis-Venture Architecture: Any shape regions
- Parameter learning:
  - Gradient method: maximize log-likelihood
  - EM algorithm: introduce latent variables, inference in E-step, update weights in M-step

Inference Methods

Differential approach:

1. Compute the marginal distribution via network polynomials
2. Interpret the probability distribution through derivatives

Goal

Image completion[1]: filling up the missing or corrupted part of an image.

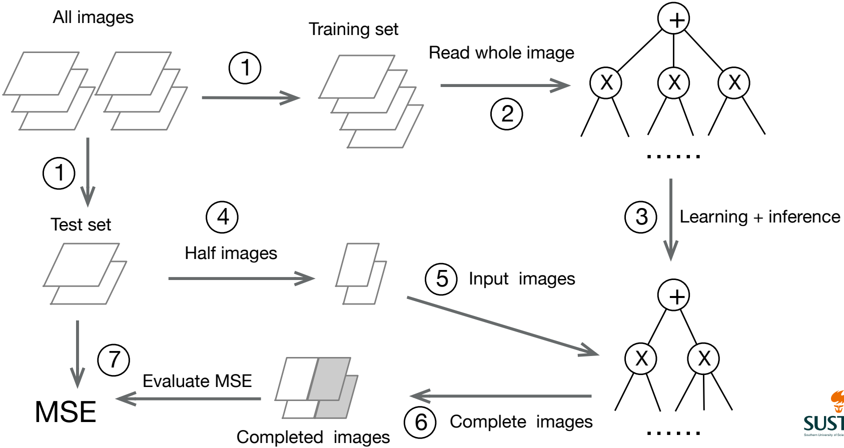
[1] Poon and Domingos, "Sum-product networks: A new deep architecture".

Enviroment

Enviroment:

- Platform: TaiYi
- Library: OpenMPI C++
- Dataset:
  - **Caltech**:
    - 101 categories, from 40 to 800 images per category
    - about 300×200 pixels, rescaled to 100×64 pixels
  - **Olivetti**:
    - face images taken between Apr. 1992 and Apr. 1994 at AT&T Laboratories Cambridge
    - size 64×64 pixels

Process


All images
Training set
1
Read whole image
2
+
X
X
X
......
1
Test set
4
Half images
3
Learning + inference
5
Input images
+
X
X
7
Evaluate MSE
MSE
Completed images
6
Complete images
......

Poon-Domingos Architecture

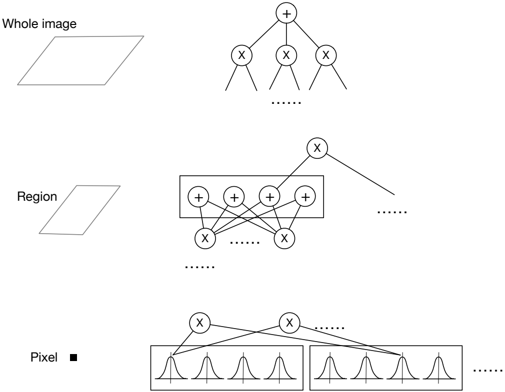


Figure: Poon-Domingos Architecture

Experiments

Factors: number of cores, input size

Experiments:

1. **Caltech**: 80 cores, **Olivetti**: 40 cores, size 64×64
2. **Caltech**: 120 cores, **Olivetti**: 80 cores, size 64×64
3. **Caltech**: 80 cores, size 100×64
4. **Caltech**: 120 cores, size 100×64

Poon's experiments: **Caltech**: 102 cores, **Olivetti**: 51 cores, size 64×64

Exp #1 vs. Exp #2: number of cores

Exp #1 vs. Exp #3 and Exp #2 vs. Exp #4: input size

Comparison on MSE(1)

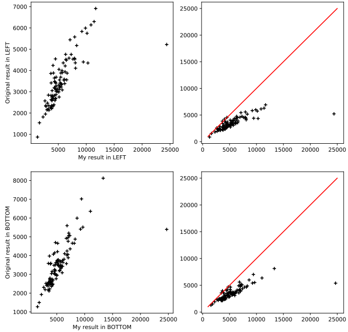


Figure: Exp. #1 vs Poon's(Caltech)

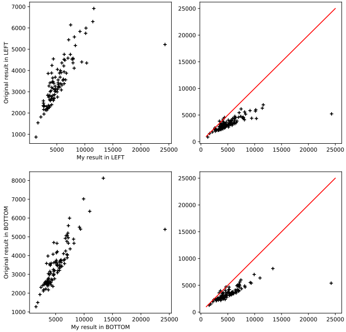


Figure: Exp. #2 vs Poon's(Caltech)

Comparison on MSE(2)

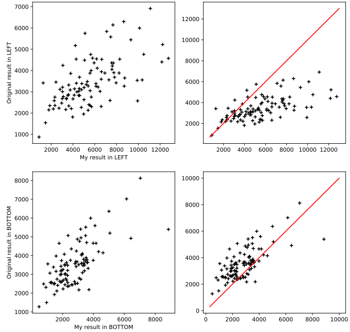


Figure: Exp. #3 vs Poon's(Caltech)

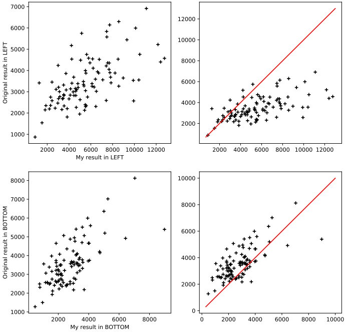


Figure: Exp. #4 vs Poon's(Caltech)

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Comparison on Number of Cores

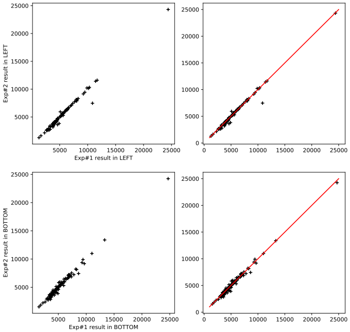

Figure: Exp. #1 vs Exp. #2(Caltech)

Comparison on Input Size

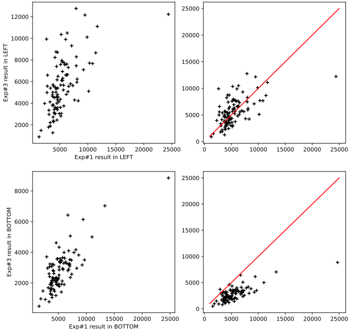

Figure: Exp. #1 vs Exp. #3(Caltech)

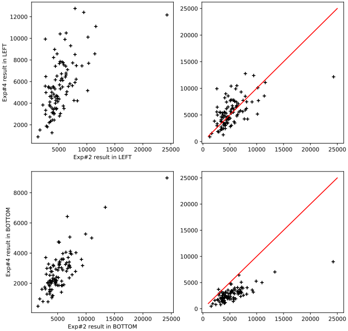

Figure: Exp. #2 vs Exp. #4(Caltech)

Comparison on Image(1)

Figure: Airplanes-bottom(Poon's, Exp. #2, Exp. #4)

Figure: Yin_yang-left(Poon's, Exp. #2, Exp. #4)

Comparison on Image(2)

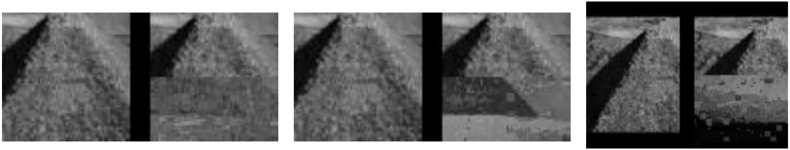

Figure: Pyramid-bottom(Poon's, Exp. #2, Exp. #4)

Figure: Sunflower-bottom(Poon's, Exp. #2, Exp. #4)

Comparison on Time

Time Cost	Poon's	Exp. #1	Exp. #2	Exp. #3	Exp. #4
Caltech-101	≤ 2 hours	≤ 4 hours	≤ 7 hours	≤ 11 hours	≤ 19 hours
Olivetti	within a few minutes	≤ 4 minutes	≥ 72 hours	Nan	Nan

Table: Time Cost of Poon's Experiments and My Experiments

Analysis

Conclusion:

- Number of cores makes no influence
- Larger input size leads to lower MSE
- My implementation is valid

Why:

- Randomness in architecture
- Difference between implementation
- Complexity of model

Conclusion

Conclusion:

- My implementation is valid and the reproduction is successful
- Reproduction is not easy

Future Work

Future work:

1. Architecture improvement
2. More applications
3. New algorithms for learning and inference

Acknowledgement

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Thanks

Thanks for listening!

Q & A

Questions ?