1. **Graph-Based Semi-Supervised Learning**

### Input:
\[ G = (V, E) \]
\[ X \text{, features matrix} \]
\[ Y \text{, a part of labels} \]

### Output:
Labels of unlabeled nodes

2. **Graph Signal Processing (GSP)**

### Graph Laplacian:
\[ \mathbf{L} = \mathbf{D} - \mathbf{W} \]
where \( \mathbf{D} \) and \( \mathbf{W} \) are degree matrices.

### Eigen Decomposition:
\[ \mathbf{L} = \Phi \Lambda \Phi^{-1} \]

### Convolutional Filer:
\[ \mathbf{G} = \Phi \Lambda \Phi^{-1} = \mathbf{p}(L) \]

### Convolution:
\[ \mathbf{Z} = \mathbf{G} \mathbf{X} \]

### Low-pass Filter:
\( \mathbf{p}(z) \) reserve low frequency signals and remove high frequency ones.

3. **Revisit and Generalize Label Propagation (GLP)**

### Dissecting LP [4,5] into Signals, Filters, and Classifiers

### GLP:
\[ \mathbf{X} \]
\[ \mathbf{Z} = \mathbf{G} \mathbf{X} \]

### Any low-pass graph Filter

### Frequency matrix as graph signals

### Prediction

### Improved GCN (IGCN):

\[ Z = \text{softmax}(\mathbf{W}_i^{(L)} \text{ReLU}(\mathbf{W}_j^{(0)} \mathbf{X}(\theta(0))^{(1)})) \]

IGCN can achieve label efficiency by using the exponent \( k \) to conveniently adjust the filter strength. In this way, it can maintain a shallow structure with a reasonable number of trainable parameters to avoid overfitting.

5. **Experiments**

### Table 1. Classification accuracy and running time on citation networks and NELL.

### Table 2. Zero-Shot Image Recognition

### References

[1] Csáji, M., and V. V. Ábrahám, “Discrete signal processing on graphs”.


**Table 1.** Classification accuracy and running time on citation networks and NELL.

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**Table 2.** Zero-Shot Image Recognition

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