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論文 / 著書情報
Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	情報工学 系 知能情報 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 学術 ）
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

A network is fundamentally a projection of real-world observations. In its simplest form, it consists of just nodes and edges. For instance, in a social network, the nodes represent people, and edges represent the relationships among these people. The abstraction of networks from real-world observations permits the studies of complex systems. Deconstructing such complex systems to machine comprehensible format provide numerous means of application and theoretical studies. Among these applications and theoretical studies, the study of summarizing patterns in networks is an intriguing one. It allows one to comprehend complex behaviors by finding a group of nodes with similar patterns. In network science, such a study is called community detection.

From models that solely focus on determining the quality of communities to those that study the behavior of a network, network modeling with community structure is undeniably useful. The fundamental study of understanding the causality and properties of the existence of such networks is challenging. If one assumes a model could simulate the behavior of networks with community structure with precise accuracy, one can solve many real-world problems. Unfortunately, such a model does not exist. Community structures today have no universal definitions. The definition varies from a very restrictive definition of subgraph density to a generalized view of stochasticity. In other words, such a definition requires a thorough understanding of the task at hand.

Although coming to a universal definition of community structure is an upheaving task, there are several ways to approach this problem. Literature from the past has circumvented the idea of defining community structures as a generalized behavior or stochasticity. One can find a group of nodes that behaves similarly with some uncertainty. Leveraging on ideas of machine learning, researchers in the past proposed the Stochastic Blockmodel (SBM) as a means of learning community structures via model selection. The study of SBM has contributed insights to community structures but remain to be restrictive in its applications. For instance, learning community structures with features is a non-trivial problem for SBM to solve.

Motivated by the idea of finding community structures with no universal definition, this thesis seeks to propose a model that learns a community structure automatically through Bayes' model selection process. It includes principles from a variational perspective by attempting to solve a computationally intractable problem within tractable means. This thesis combines both approaches by proposing a variational learning framework that accommodates different use cases, such as networks with or without features.

In this thesis, a model for community detection is proposed. The proposed model is a generative model for learning community structures and exhibits several important properties. Namely, such properties include generative capabilities, a structure-agnostic definition for community detection, and theoretical guarantees for convergence. The proposed model is called Variational Graph Autoencoder for Community Detection (VGAECD). It follows a Variational Autoencoder framework, which consists of an encoder-decoder architecture and is optimized via amortized variational inference. The encoder-decoder architecture permits learning in an unsupervised manner. In practice, this is important because labels are scarce and costly to obtain. Furthermore, variational methods are known to have faster convergence and better scalability than conventional sampling methods like Markov Chain Monte Carlo.

The organization of this thesis begins with an introduction to the building blocks of the proposed model. These building blocks are emphasized to show the importance of community detection and network modeling. The fusion of both studies is a stepping stone towards the motivation of proposing a generative model

for community detection. Motivated by this, the proposed model is derived and scrutinized. Thorough evaluations are performed on the proposed model to evaluate its quality on both synthetic and real-world datasets. The outcome of this evaluation shows that the model outperforms existing state-of-the-art algorithms in the recovering community structures.

Since the proposed model is an unsupervised learning model, a major weakness is observed. The weakness is inherent in unsupervised models that are optimized through stochastic gradient descent. These models have a tendency to exhibit a deviation of objective functions such as clustering and reconstruction recovery. In the second part of this thesis, the initial model is further optimized and improved. A more compact encoder is formulated and optimized with a dual-optimization procedure. The encoder is simplified using Simplified Graph Convolution, which results in a fewer number of parameters to train. Meanwhile, the proposal of dual-optimization ensures that the weakness observed earlier is alleviated.

Towards the last part of this thesis, the challenges observed in the variational framework are discussed. The study targets scalability and sensitivity analysis on the hyperparameters of the proposed model. For applications, several use cases that leverage on the proposed framework are proposed. Finally, this thesis ends with a concluding remark and a possible future extension.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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