**TELKOMNIKA Indonesian Journal of Electrical Engineering**
Vol. 12, No. 8, August 2014, pp. 6411 ~ 6416
DOI: 10.11591/telkomnika.v12i8.5331


# Small-world and Scale-free Features in Harry Potter

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***Abstract***

*Harry Potter is a series of seven fantasy novels which has got a huge success. To explore the reasons of so successful of the novel behind, we analyzed the characters network in Harry Potter from the perspective of complex networks. Studies show that the characters network in Harry Potter has got the small-world effect and scale-free feature. It is a typical complex network. The success of novel Harry Potter is precisely due to the complex properties of it, and this may give some guidance for novel writers when preparing their works.*

***Keywords****: complex networks, small-world, scale-free, rich–club, Harry Potter*



## 1. Introduction

A network is a set of items, which we called vertices or nodes, with connections between them, called edges or links. Systems taking the form of networks abound in the world. For example, the Internet is a network of routers or domains. The World Wide Web (WWW) is a network of websites. The interpersonal network is constructed by the patterns of friendships between individuals. The scientific citation network is a network of citations between academic papers. The collaboration network is a network in which participants collaborate in groups of one kind or another. The brain is a network of neurons. An organization is a network of people. Food webs and metabolic pathways can all be represented by networks, and even a language can also be regarded as a network which is constructed by the words and the relationships among them.

Over the past few years, complex networks have received many attentions from a wide range of experts in various fields and have been intensively studied across many fields of science. A wide range of real world networks, from the Internet [1, 2], WWW [3, 4] to email communications [5, 6], from large power networks [7] to the global transportation networks [8-11], from the organism in the brain [12], the protein interaction networks [13] to a variety of metabolic networks [14, 15], from the scientific collaboration network [16-18] to a variety of economic [19], from the supply chain network [20] to food webs [21-23], from the semantic networks [24] to the software networks [25-27], etc., can all be studied from the perspective of complex networks. It was found that although these networks are from different areas, representing different systems, but all have a similar small-world and scale-free features. It can be found that complex network theory has become a powerful tool to analyze the structure as a whole and its dynamical properties of various types of complex systems.

The novel is a reflection of the real world. The characters network in a novel is similar with the interpersonal network of the real world. To explore the reasons of the success of novel Harry Potter, we analyzed the characters network in it from the perspective of complex networks.

## 2. Extraction of the Characters Network in Harry Potter

Harry Potter [28] is a series of seven fantasy novels written by the British author J. K. Rowling. Since the release of the first novel “Harry Potter and the Philosopher's Stone” on 30 June 1997, the books have gained immense popularity, critical acclaim and commercial success worldwide. As of June 2011, the book series has sold about 450 million copies, making it the best-selling book series in history, and has been translated into 67 languages [29].

*Received December 10, 2013; Revised April 20, 2014; Accepted May 9, 2014*

The characters network in Harry Potter is constructed by the persons appeared in the novel and the relationships among them. We choose the persons except goblins, house-elves and ghosts appeared in the novel as nodes and take the relationships between the persons as links to construct the characters network. If two persons are friends or they have combated face to face in one battle, there is a link between them. In order to obtain a connected network, the characters network does not contain the persons once appeared in the novel but have no contact with the other characters, such as some freshmen mentioned in the Sorting Hat and the players of Bulgarian Quidditch team and Irish Quidditch team in Quidditch World Cup, etc. Finally we got a network with 317 nodes and 1146 links.

## 3. The Small-world Effect in Harry Potter

The small-world effect is one of the significant recent discoveries in the field of complex networks. In 1998, D. J. Watts and his advisor S. H. Strogatz in the Cornell University of United States published a paper entitled “Collective dynamics of ‘small-world’ networks” in Nature, revealing the small-world feature shared by many real-world networks [30]. By saying small-world, it means the network has small average path length and large clustering coefficient. So we analyzed the average path length and clustering coefficient of the Characters Network in Harry Potter.

We first computed the average path length of the characters network in Harry Potter, which is 2.7399. It is small compared with the total number of the nodes in the network. The two main characters in the novel are Harry Potter and Lord Voldemort. The story is expanded around them. Most characters of the network can be found through Harry Potter or Lord Voldemort which results in the small average path length of the network.

On the other hand, we also computed the clustering coefficient of the characters network in Harry Potter, which is 0.4132. In the novel of Harry Potter, the main characters are Harry Potter and Lord Voldemort. The other characters are arranged around them. The friends of Harry are friends of each other, and the Death Eaters around Lord Voldemort are familiar with each other. So the clustering coefficient of the characters network in Harry Potter is high.

In summary, the characters network in Harry Potter has small average path length and large clustering coefficient. So it is a small-world network which made the novel plot compact and spellbinding. It laid the foundation for the success of novel Harry Potter.

## 4. The Scale-free Feature of the Characters Network in Harry Potter

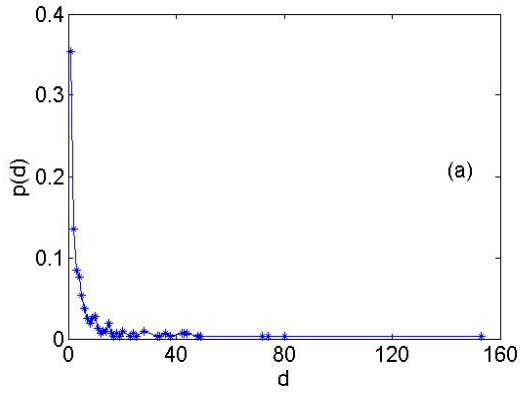
Another significant recent discovery in the field of complex networks is the observation that many large-scale complex networks are scale-free. In 1999, Professor A. L. Barabási and his Ph. D student R. Albert published a paper entitled “Emergence of scaling in random networks” in Science, revealing the scale-free feature shared by many real-world networks [31]. By saying scale-free, it means the degree of nodes obeys the power-law degree distribution. That is most nodes have very few links and yet a few nodes have many links.

We analyzed the degree distribution of the characters network in Harry Potter, which is shown in Figure 1. It can be seen that the degree distribution of the characters network in Harry Potter satisfied power-law. The exponent of the distribution is 1.2835.

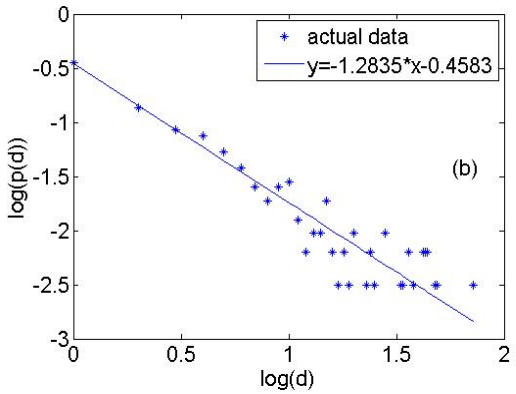
The books of Harry Potter chronicle the adventures of a wizard, Harry Potter, and his friends Ronald Weasley and Hermione Granger, all of whom are students at Hogwarts School of Witchcraft and Wizardry. The main story arc concerns Harry's quest to overcome the Dark wizard Lord Voldemort, whose aims are to become immortal, conquer the wizarding world, subjugate non-magical people, and destroy all those who stand in his way, especially Harry Potter.

The first five nodes that have got the biggest degree in the characters network in Harry Potter are Harry Potter, Ronald Weasley, Albus Dumbledore, Hermione Granger and Lord Voldemort respectively. Harry Potter and Lord Voldemort are two main characters in the novel. Ronald Weasley and Hermione Granger are Harry’s best friends. They together completed a number of tasks successfully. Albus Dumbledore is the heart and soul of the novel, links the past and now of Hogwarts School. They have a large of followers. Lord Voldemort is the leader of Death Eaters. He has also got a large of followers. So they have got a large of links, and most of the other persons in the novel are arranged for them, so they only have got a few links

that leading to the power-law degree distribution. And this made the main characters in the novel prominent and distinctive.




(a) the degree distribution




(b) the fitness of figure (a) under the logarithm coordinates

Figure 1. The Degree Distribution of the Characters Network in Harry Potter

## 5. The Other Properties of the Characters Network in Harry Potter

### 5.1. Degree Correlation

Degree correlation of a network can be described by the average degree of nearest neighbors. The average degree of nearest neighbors of the nodes with degree $d$, $d_{nn}(d)$, is defined as followed [32]:

$$d_{nn}(d) = \frac{1}{n_d} \sum_{j/d_j=d} \frac{1}{d_j} \sum_{i \in V(j)} d_i \quad (1)$$

Where $V(j)$ is the set of the neighbor nodes $d_j$ of node $j$, $n_d$ is the number of the nodes with degree $d$.

If $d_{nn}(d)$ increases with $d$, the network is an assortative network, otherwise it is a disassortative network.

The average degree of nearest neighbors of the nodes with degree $d$, $d_{nn}(d)$, in the characters network in Harry Potter is described as Figure 2.

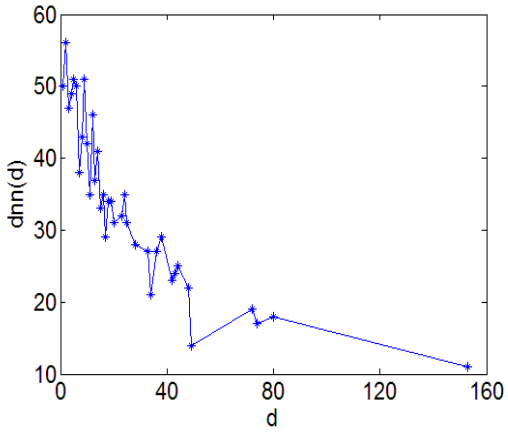



Figure 2. Average Nearest Neighbors as a Function of the Degree of the Characters Network in Harry Potter

The average degree of nearest neighbors of the nodes with degree $d$, $d_{nn}(d)$, decreases with degree $d$ from the whole in the characters network in Harry Potter which means that the network is a disassortative network, that is the nodes with lower degree tend to connect with the nodes with higher degree.

There are only a few main roles in the novel. The most persons are supporting roles. They are familiar with Harry Potter, Albus Dumbledore, or Lord Voldemort. So the nodes with lower degree likely to connect with the nodes with higher degree, and the most neighbors' degree of the nodes with high degree are lower. Thus leads to the disassortativity of the network. The arrangement of the characters in the novel made the main roles prominent and the plot compact. Thus enhance the readability of the novel.

### 5.2. The Rich-club Feature of the Characters Network in Harry Potter

The rich–club phenomenon means that the rich nodes, which are a small number of nodes with large numbers of links, are very well connected to each other. The rich–club is characterized by the rich–club connectivity which measures the interconnection between rich nodes.

The rich–club connectivity is defined as the ratio between the number of links that actually exist among the first $r$ percent nodes with the biggest degree and the total possible number among them, namely,

$$\varphi(r) = \frac{2E(n(r))}{n(r)(n(r)-1)} \tag{2}$$

Where $n(r)$ is the number of the first $r$ percent nodes, $E(n(r))$ is the number of the links that actually exist among $n(r)$ nodes.

Figure 3 shows the rich–club coefficient $\varphi(r)$ against percentage $r$ of the characters network in Harry Potter. It shows that the rich nodes of the network very well connected between each other. The top 1%, 5% and 10% rich nodes have 100%, 81.9% and 55.3% of the maximum possible number of links separately.

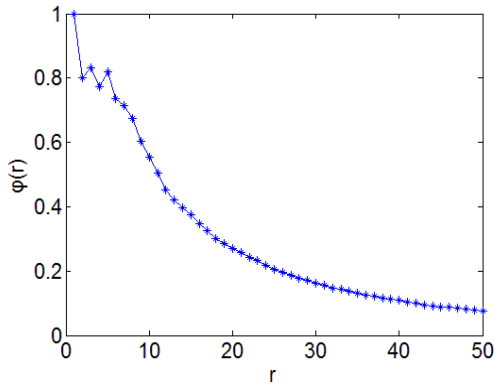



Figure 3. Rich–club Connectivity $\varphi(r)$ Against Percentage $r$ of the Characters Network in Harry Potter

The rich nodes in the network are the main characters in the novel, most of them are familiar with each other, and this results in the rich-club phenomenon.

The other properties of the characters network in Harry Potter are listed in Table 1.

Table 1. The Properties of the Characters Network in Harry Potter

| Max degree | Average degree | Coreness | Diameter | Assortative coefficient |
|---|---|---|---|---|
| 153 | 7.2303 | 12 | 7 | -0.2654 |

## 6. Conclusion

Studies show that the complex network does not only exist in the real world, but also exist in the virtual world. By analyzing the characters network in novel Harry Potter, we find it is a typical complex network. There is the small-world effect and scale-free feature in it. It has got the same properties with the most complex networks in the real world. Although the characters in the novel are numerous, but the main characters are outstanding, they have distinctive personality. All plots are expanded around them. These result in the small average path length and large clustering coefficient. The main characters all have a number of followers which results in the scale-free feature. The complex network properties of the characters network in the novel made the characters vivid and vigorous, the plot thriving and spellbinding and captured the imagination of millions of readers, young and old, across the globe and created a miracle in the history of publishing. It is the complex properties of the characters network in the novel combined with the ingenious ideas, rich imagination and flexibility of writing of the writer made the novel got huge success.

Whether each successful novel has the complex properties? This needs us to further study. If it is true, it will give guidance for the novel writers when preparing their works, and can also help publishers to decide whether a novel can bring them the benefit or not.

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