Entrepreneurship in the Eyes of Network Science

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Abstract

Network based research in entrepreneurship endures to grow in coming years [1]. Social Network Analysis (SNA) is not known as traditional data mining technique, but it can be used for mining interested patterns in large data. Entrepreneurs are usually connected with the agents known as brokers (in SNA perspective) in order to advance their strategic position in networked space [2]. The aim of this article is twofold. First, introduce concepts of network science and present a model of dependence centrality with an application of hypothetical small network of entrepreneurs; second, differentiate the model with betweenness centrality and pair dependency with theoretical and practical implications in the area.

Keywords: Betweenness centrality; dependence centrality; entrepreneurship; network analysis; pair dependency model.

1. Introduction

Entrepreneurship is defined as “The capacity and willingness to develop organize and manage a business venture along with any of its risks in order to make a profit. The most obvious example of entrepreneurship is the starting of new businesses"\textsuperscript{†}.

An entrepreneur is known as the person, who owns, launches, manages, and able to take sole responsibility of the economic endeavor [3]. A simple definition of entrepreneur is “a person who starts a business and is willing to risk loss in order to make money"\textsuperscript{‡}. It is very important to remember that the common keywords are business and risk. An entrepreneur is recognized to have a real business and able to take risk. Risk-taking is known as the synonym for entrepreneurship. To start and support a business, an entrepreneur has to put his/her career, personal finances and even mental health at stake.

When entrepreneurs decide to start a new venture in the form of business, it is common that they may face with number of problems. The authors [4] posit that the entrepreneurs need to find a project start-up that stand

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\textsuperscript{†} http://www.businessdictionary.com/definition/entrepreneurship.html#ixzz4AEgJxQhq

\textsuperscript{‡} http://www.merriam-webster.com/dictionary/entrepreneur
for acceptable profit potential in order to compensate for the cost of the start-up of the project and other related expenses; a liquidity premium for the time and capital to be invested, risk bearing premium be kept in mind. It is obligatory to organize the resources needed to bring that opportunity to success [5]. It is important that the project involves one entrepreneur and a network of entrepreneurs looking into the size of the project (small, medium or large). The authors [4] also advised that it would promising to identify the opportunities for the next project and keep in mind how other opportunities will come from? As we are living in the connected world, therefore, defining network perspective within entrepreneurship research would be promising. Hoang and Antoncic [6] mentioned that the main advantage of network science in the area of entrepreneurship is the access of information, advice, problem solving. The literature study shows that entrepreneurs regularly use networks in order to get ideas and gather information to be familiar with new opportunities in the area. It is the use of network science, so that entrepreneurs keep in contact with distributors, suppliers, competitors, customers and also with their employees.

It is expected that more than one firm can be run a group of entrepreneurs. There might be lot of chances for the failure of new business, and it is common that the entrepreneurs will start a new firm when a firm could not succeed (in case of loss of economic growth). Network science is used to understand how entrepreneurs use connected world in order to design, launch and run a new business [7-8]. In order to develop a new business requires human and social capital, and network science provides access to diverse set of novice or experienced entrepreneurs (human capital) and different resources (social capital).

For the establishment of a business, network science explores the relationships between entrepreneurs and others that are responsible for the resources [9-10]. Entrepreneurs have capability to run the business, and need human and social capital in order to obtain and supply their products and services [11]. Network science provides assistance to entrepreneurs in order to get support and access to diverse channels of distribution and the science of networks provides interaction between people and organizations which broaden the accessibility of resources that sustain a new firm [12].

Network science is the area which has diverse characteristics for entrepreneurs, e.g., size, position and structure of a network of entrepreneurs. By enhancing the size of the network, the entrepreneurs may get important knowledge from others. In order to find different position entrepreneurs may be able to find different roles (leader, broker, peripheral) in the network. The structure of the network may be helpful for entrepreneurs in order to organize, and expand the opportunities which are available to the entrepreneur [13].

In network science literature [14], “researchers have examined a comprehensive variety of ties; including communication ties (e.g., who dialogues to whom or who provides info or guidance to whom), ceremonial ties (e.g., who reports to whom), emotional ties (e.g., who loves whom, or who reliance on whom), material ties (e.g., who gives training material or other incomes to whom), and proximity ties (e.g., who is close to whom). In network science, the networks are usually identified as of multiplex nature, that is, more than one type of ties is shared between the entrepreneurs. For example, two entrepreneurs might have a ceremonial tie (one is new entrepreneur and working under the guidance of the other entrepreneur, who has lot of experience) and an emotional tie (they are friends) and a proximity tie (they are residing in the same apartment and their flats are two doors away on the same floor”).

The study [14] demonstrates a number of connections (aka relationships/ties), “the ties may be directional (the entrepreneur A gives advice to entrepreneur B vs. entrepreneur B gets advice from entrepreneur A) or non-directional (entrepreneur A attends a meeting with entrepreneur B at Asan, South Korea). The ties may differ in content (entrepreneur A talks with entrepreneur B about the trust of his colleagues working in the enterprise) and entrepreneur A explains about the outcomes of the meeting in Dubai with entrepreneur B), or vary frequency in terms of time (hourly, daily, weekly, monthly, annually, etc.). The ties may also vary in the way of communication/exchange of information (frontal conversation, written memos, email, fax, instant messages, live chat, Skype or Facebook messages, twitter messages, etc.) or the ties may differ in sign, ranging from negative to positive”.


Network Science is used in a number of areas [15], for instance, business specialists use network science to determine the active ties between employees that enable the work to get done; these relationships usually vary from the relationships seen in an organizational chart, i.e., hierarchical structure [16]. It should be noted that centrality is one of most important network properties that commonly have been used to study actors [17] — here actors are entrepreneurs. The overall idea of centrality involves a number of dissimilar features of the “importance” or “visibility” of actors/entrepreneurs in a network. An analysis of main centrality measures is available in the research article [18] and the article has contributed greatly to the theoretical application and conceptual clarification of centrality.

An entrepreneur’s position in a network can be determined using centrality, where a central entrepreneur may reach many entrepreneurs within one network using shortest distance [19]. On the other hand, a peripheral entrepreneur may reach to few entrepreneurs within the same network and distance to the central entrepreneur may be larger. It is possible that the peripheral entrepreneurs may be connected to other networks, and due to the presence of peripherals, the distance to other networks become shorter [20]. Freeman [18] offers three types of common measures of centrality, known as “degree”, “closeness”, and “betweenness”.

Network science is the primary communication key considered by entrepreneurs since years for interpersonal interactions and promoting innovative ideas particularly in high tech circles [26]. Today, the networking activity is shifted towards the virtual world because of the fact that most of the high tech innovative activities are nowadays discussed and shared through online social networks, such as LinkedIn, Facebook, Twitter, MySpace and these forums grow into a main channel of keeping in touch with the business partners. This is the main idea behind this research and leads to the question: Do the network science benefits the entrepreneurs/business partners in order to understand the whole structure of the network?

Network science is used to detect the whole structure of a business. For example, who are core members in the network and who are the peripherals? This kind of questions can be dealt by using centrality models as mentioned in the article [18]. But, in this article, we restrict ourselves to ask a question how much entrepreneurs depend on other entrepreneurs. To answer this question, we present dependence centrality model and differentiate it with betweenness centrality and pair dependency [21].

The rest of the paper is organized as follows: Section 2 discusses dependence centrality, while Section 3 and Section 4 distinguish between dependence centrality with betweenness centrality and pair dependency respectively. Lastly, Section 5 concludes the paper mentioning possible directions for future work.

2. Dependence Centrality

In this Section, we present a new recently introduced dependence centrality measure [22]. Dependence centrality discusses much as an entrepreneur or the entrepreneurial firm is dependent on other entrepreneurs in a network. The relation of a network is in symmetric form, for example, “relates with” for a set of entrepreneurs. When a pair of entrepreneurs (for instance, \(u \) and \(v\)) is connected by a relation in way that the entrepreneurs directly interconnect without any mediators, the entrepreneurs are said as adjacent. On the other hand a set of relations connecting two or more entrepreneurs \((u, v, w)\) such that the entrepreneur \(u\) would like to communicate with the entrepreneur \(w\), using the entrepreneur \(v\) (as a mediator), then we have to discover how much the entrepreneur \(u\) uses the entrepreneur \(v\) to reach at the entrepreneur \(w\). It should be kept in mind, we use shortest paths used by entrepreneur \(u\) in order to reach to the entrepreneur \(w\). It is obviously seen that there can be more than one shortest paths (also known as geodesic), connecting any pair of entrepreneurs [23]. Mathematically, the dependence centrality is described as under:

Let \(\zeta(u, v)(w) = \) factor of dependency of the entrepreneur \(u\) on the entrepreneur \(v\) in order to reach another entrepreneur \(w\) in the network as mentioned in (1):
\[ \zeta_{(u,v)}(w) = \frac{\text{Occurrence } (u,v)}{d(u,v) \times \text{path } (u,w)} \] (1)

It should be noted that is the time (how much time) the entrepreneur \( u \) uses the entrepreneur \( v \) as mediator, whereas \( \text{path } (u,w) \) is the geodesic between the entrepreneur \( u \) and the entrepreneur \( w \), and \( d(u,v) \) is the shortest path between the entrepreneur \( u \) and the entrepreneur \( v \).

As mentioned earlier, the dependence centrality of an entrepreneur discovers maximum/minimum amount of dependence between the entrepreneurs (usually the entrepreneurs who are adjacent to each other), are always important for that entrepreneur, as all activities of that entrepreneur depend on the entrepreneurs that are adjacent to it (or directly connected to that entrepreneur).

Hence, the dependence centrality is defined as “the point at which an entrepreneur, \( u \), needed to depend on other entrepreneur, \( v \), in order to transfer its communications to and from along shortest paths of all other accessible entrepreneurs in the network”. Therefore, the dependence centrality of the entrepreneur \( u \) on entrepreneur \( v \) in a network containing \( n \) entrepreneurs can be found by using mathematical model as shown at (2):

\[ C_{\text{dep } (u,v)} = 1 + \sum_{w=1}^{n} \zeta_{(u,v)}(w), \quad u \neq v \neq w \] (2)

It is important to note that the network is connected, therefore, 1 is used in the model (RHS), in case the network is not connected, then 1 is replaced by 0.

To calculate the dependence of entrepreneurs in the network, the results are arranged in a matrix \( D = [ C_{\text{dep } (u,v)} ] \). It should be noted that the matrix can be normalized by diving each value with \((n-1)\), where \( n \) represents the total number of entrepreneurs present in a network.

An analyst can easily be benefited by using the dependence matrix because the matrix provides a clear picture in comparison to other centrality measures (for example, closeness centrality, betweenness centrality and pair dependency), not only identifying an amount of particular entrepreneur is dependent (for example, maximum dependency/minimum dependency) on others but also discovering the amount of dependency of other entrepreneurs on that particular entrepreneur.

Fig. 1 shows a hypothetical network of entrepreneurs, where the entrepreneurs \( a, b, \) and \( c \) illustrate a comparatively low score based on overall centrality. The sum of each entrepreneur \( (a, b, c) \) is nearly 1, in contrast to the sum of other entrepreneurs in the network. Table 1 shows the summary of dependency matrix. The lowermost sum of values in a row shows the entrepreneurs that are most challenging to be removed; their infrastructures are slightest impaired by separation of the other entrepreneurs (in case of bankruptcy, etc.). These entrepreneurs are least reliant on others and the communications are evenly distributed. On the other hand, the uppermost sum of values in a row shows that the entrepreneurs that can be easily removed, these entrepreneurs are typically reliant on other entrepreneurs in the network.

Considering the Table 1, the lowermost sum of values in a column expresses the lowest communication takes place through these entrepreneurs. The damage of these entrepreneurs will be of minimum harmful for a network. However, the maximum sum of values in a column shows that the elimination of those entrepreneurs would be troublesome for the network. An analyst may be able to look total picture of the entrepreneurs in a network, and be familiar about the strengths and flaws of the entrepreneur being considered after loss/removal.
In the following Sections, we distinguish between dependence centrality with betweenness centrality and pair dependency.

3. Difference between Dependence Centrality and Betweenness Centrality

Betweenness centrality is defined as “the frequency at which an actor occurs on a geodesic that connects a pair of nodes” [24]. Accordingly, any actor that travels on a shortest path amongst other nodes can possibly control the communication of information or outcome interchange by being an intermediary actor. This measure is known as “the potential for control that defines the centrality of these nodes” [25]. Therefore, if two entrepreneurs, say entrepreneur \(a\) and entrepreneur \(c\), are associated only through the entrepreneur \(b\), then entrepreneur \(b\) would fall between the entrepreneurs \(a\) and \(c\) and would have control of most of the resources that flow between the actor \(a\) (entrepreneur \(a\)) and the actor \(c\) (the entrepreneur \(c\)). This measure can be used for discovering gatekeepers in the network.

The results of betweenness centrality of the network shown in Fig. 1 are tabulated in Table 2. It is to note that the betweenness centrality of the actors \(a\) and \(b\), i.e., entrepreneur \(a\) and entrepreneur \(b\) is zero, because of the minimum amount of communication between these entrepreneurs (actors). Therefore, we may conclude

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Table 1. Dependence matrix of the network shown in Fig. 1.

<table>
<thead>
<tr>
<th>Entrepreneur</th>
<th>(g)</th>
<th>(e)</th>
<th>(f)</th>
<th>(d)</th>
<th>(b)</th>
<th>(c)</th>
<th>(a)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g)</td>
<td>0.25</td>
<td>0.33</td>
<td>0.42</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>(e)</td>
<td>0.17</td>
<td>0.33</td>
<td>0.33</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td>(f)</td>
<td>0.33</td>
<td>0.5</td>
<td>0.25</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td>0.33</td>
<td>0.33</td>
<td>0.25</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>0.17</td>
<td>0.58</td>
<td>0.25</td>
<td>0.42</td>
<td>0.17</td>
<td>0.17</td>
<td>1.76</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td>0.25</td>
<td>0.33</td>
<td>1.00</td>
<td>0.22</td>
<td>0.17</td>
<td>0.17</td>
<td>2.19</td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>0.25</td>
<td>0.25</td>
<td>0.22</td>
<td>1.00</td>
<td>0.17</td>
<td>0.17</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>1.50</td>
<td>2.24</td>
<td>2.38</td>
<td>1.64</td>
<td>1.02</td>
<td>1.02</td>
<td>9.02</td>
<td></td>
</tr>
</tbody>
</table>
that other entrepreneurs (actors) in the network (see Fig. 1) are not reliant on these entrepreneurs for any type of communication.

On the other hand, the dependence matrix, which is tabulated in Table 1, the results for the actors are non-zero which shows the amount of dependency of the entrepreneur $a$, $b$, and $c$ on other entrepreneurs. Looking into the Table 1, it is clear that the entrepreneur $a$ mostly depends on the entrepreneur $d$, in case the entrepreneur $d$ is bankrupted and leave the network, the entrepreneur $a$ will spontaneously be inaccessible. By examining the row of the entrepreneur $b$, which is evenly distributed, comparing the row of the entrepreneur $a$. The entrepreneur $b$ typically depends on the entrepreneur $e$ (highest value 0.58).

The entrepreneur $b$ also has more or less other options, for instance, it also reliant on entrepreneur $d$ (it has a value of 0.42). As these two entrepreneurs are not frequently in communication as result of betweenness, there is a significant difference indicated by the dependence centrality. It should be noted that if analysts desire to know which entrepreneur is to be removed due to bankruptcy or other factors (either entrepreneur $a$ or entrepreneur $b$), by looking at the dependence centrality matrix the analyst can assist in advising the loss of entrepreneur $b$ in comparison to entrepreneur $a$, because entrepreneur $b$’s removal will cause more harm than entrepreneur $a$. This shows the importance of dependence centrality in comparison to betweenness centrality.

<table>
<thead>
<tr>
<th>Entrepreneur</th>
<th>g</th>
<th>e</th>
<th>f</th>
<th>d</th>
<th>b</th>
<th>c</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betweenness</td>
<td>0.13</td>
<td>0.30</td>
<td>0.33</td>
<td>0.37</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4. Difference between Dependence Centrality and Pair Dependency

Freeman [21] in his article “The gatekeeper, pair-dependency and structural centrality” introduced a similar type of measure, which is designed and developed with different perspectives in mind. The pair dependency is developed keeping in mind the networks and it performs very well. Now we demonstrate the differences between dependence centrality and pair dependency.

Suppose the head of an institution wants to book an air ticket. S/he may ask one of his/her secretaries to book the ticket for him/her. The secretary/secretaries may contact a travel agent, who in turn coordinates with the airline to achieve the desired goal (in this case, the goal is to book the ticket). The same scenario is depicted in the network as shown in Fig. 2.

Now the important point here is to identify the most important person on which the head is most dependent upon in order to book a ticket.

The difference between the two measures, i.e., dependence centrality and pair dependency is shown in Table 2. From the discussions as mentioned in Table 2, it is obvious that both measures are different. As per experiments conducted on different networks, dependence centrality yielded promising and realistic results. From the above given proof, it is clear that outcomes of both measures (dependence centrality and pair dependency) are diverse in nature.
Table 3: The difference between dependence centrality and pair dependency

<table>
<thead>
<tr>
<th>Dependence Centrality</th>
<th>Pair Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td>The definition of dependence centrality states that the dependence of entrepreneur ( u ) on ( v ) can be discovered as mentioned in equation (2)</td>
<td>According to Pair dependency,</td>
</tr>
</tbody>
</table>
| \[
C_{dep(u,v)} = 1 + \sum_{w=1}^{n} \zeta_{(u,v)}(w), \quad u \neq v \neq w
\]
| \[
\zeta_{(u,v)}(w) = \frac{occurrence(u,v)}{d(u,v) \times path(u,w)}
\] | \[
\begin{align*}
\text{To calculate the pair dependency, when } & i=\text{head} \\
& j=\text{Secretary1} \text{ and } k=\text{airline}, \\
G_{\text{head,airline}}(\text{Secretary1}) &= 1 \\
G_{\text{head,airline}} &= 2 \\
B_{ik}(pj) &= 0.5 \\
d_{ij} &= 0.5
\end{align*}
\] |
| To calculate the dependence of head on Secretary, i.e. \( u=\text{head}, v=\text{secretary1} \) and \( w=\text{airline} \) occurrence(head, secretary1) = 1 path(head, airline) = 2 d(head, secretary1) = 1 \[
\zeta_{(u,v)}(w) = 0.5, \quad \text{therefore, dependence of head on secretary} = 1 + 0.5 = 1.5
\] | Similarly, to calculate the pair dependency, when \( i=\text{head} \) \( j=\text{travel agent} \) and \( k=\text{airline} \), |
| occurrence(head, travel agent) = 2 path(head, airline) = 2 d(head, travel agent) = 2 | \[
G_{\text{head,airline}}(\text{TravelAgent}) &= 2 \\
G_{\text{head,airline}} &= 2 \\
B_{ik}(pj) &= 1 \\
d_{ij} &= 1
\]
| Therefore: \[
\zeta_{(u,v)}(w) = 0.5,
\] | It is noted that we have not applied summation, because the only other entrepreneur available is the secretary2 and according to model, it will yield a value equivalent to that of the secretary1. |

Hence, dependence of head on travel agent:
1 + 0.5 = 1.5

It is important to note that we have not applied summation, because the only other entrepreneur available is the secretary2 and according to definition, it will yield a value equivalent to that of the secretary1.

**Conclusion**

The *Dependence centrality* shows that the *head* is equally dependent on the *travel agent* and *secretary1* both have value equal to 1.5.

<table>
<thead>
<tr>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>The <em>Pair dependency</em> measure suggests that the <em>head</em> is more dependent on <em>travel agent</em> ( (d_{ij}=1) ) than on the <em>secretary1</em> ( (d_{ij}=0.5) ).</td>
</tr>
</tbody>
</table>

5. **Discussion and Conclusions**

In this article, we explored the importance of network science in the area entrepreneurship. One of the major uses of theory network science is SNA, which is not known as a traditional data mining technique, but can be used to discover most important actors in a network. SNA offers a toolbox of graph algorithms that can easily detect the relational profile of entrepreneurs. One of such pathway for detecting the relational structure of the networks is known as centrality measures in networks science. In this article, we described the usage of dependence centrality with an example of small hypothetical network of entrepreneurs. We distinguished dependence centrality with betweenness centrality and pair dependency. In the future, we plan to further extend the different centrality models by predicting the potential entrepreneurs with respect to geographical locations. We also plan to find cohesion between entrepreneurs by extending models or introducing new measures. To conclude, our study may shed a new light to comprehend dependence factors of entrepreneurship.

5.1. **Implications for theory**

The study primarily contributes the theory of network science and the performance of entrepreneurs by introducing new model of dependence centrality. The model compares the difference between betweenness centrality and pair dependency.

This is important finding for a number of reasons. First, it contributes in the work of network science (also known as SNA) by the introduction of a novel measure in the form of dependence centrality. Second, the newly introduced model is distinguished with two models in the area of network science, known as betweenness centrality and pair dependency. Third, theoretically, it is assumed that the hypothetical network is partner network of entrepreneurs and the business can only be executed on trust and tightly coupled through extensive communication and information sharing. From dependence matrix, the entire structure of the network is visible in order to detect who is depending on whom and how much.

5.2. **Implications for practice**

The success of every business depends on the partners who are working together and sharing information. Project-endeavors usually bring together members who supply resources that are shared to satisfy the resource
requirement for the project vision [4]. Dependency centrality would practically assist the partner network of entrepreneurs because dependence structure would be visible to all partners and the partners would become ready in case anyone leaves the network in order to open his/ her own business or join another company as a business partner.

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