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The Potential Benefits of Analysing Geographical Networks in Adult Education

Networks

The importance of various relationships has been proven in practice several times. We can find actual examples in our own lives – when considering the events of a particular day, we will see that those activities of ours which were successful were related to our participation in numerous networks of various kinds. We may start the list with the transport network that helps us get to work and also mention the communications network that facilitates the location and redistribution of information, or our very own social network where our friends and acquaintances supply us with news. In the meantime, larger networks which are hidden from the eye, such as the economy, nature, or culture are also at work.

Living is apparently impossible without networks, yet we pay little attention to them and consider them only at the level of everyday practice. We could certainly improve our roles and the efficiency of our actions within networks if we knew more about them and learnt about their operational principles.

This topic is considered in the books of Albert-László Barabási and Péter Csermely, which introduce the topic in a popular form to the wider public.

For a long time, networks were modelled using Pál Erdős and Alfréd Rényi's theory about random graphs, where the connections between nodes are completely arbitrary [1, 2]. Barabási and his colleagues, however, discovered that certain networks do not follow this random scheme at all. Their first subject was the World Wide Web, where they examined the system of home pages and the system of hyperlinks. In this case, degree distribution follows a particular power function, also known as scale independent distribution. While attempting to explain the organizing principles of scale independent networks, the researchers discovered several specific internal characteristics belonging to these complex systems.

The experiment of Stanley Milgram (1967) [3] highlighted the phenomenon of "small worlds". This means that in large, complex systems with numerous components, such as a society populated by humans, the Internet with its home pages, or a living organism composed of cells, the length of the path between two points, no matter how distant they are otherwise, is surprisingly short. In Milgram's experiment, the number of links needed to connect two people who did not know each other was on average four to six. On the World Wide Web, we may navigate from every single page to any other in an average of nineteen clicks.

When developing the rules for scale independent network models, Barabási and his associates discovered, among other things, that unlike in the classic random graph model, new elements are continuously added to the original complex system. When this happens, the new elements are more likely to be linked to nodes that have a greater than average number of connections to others. This principle is termed "the rich get richer" and real life proves the theory here, as people are keener to befriend those who are popular and to visit places that are well-frequented, etc.

When examining the behaviour of the Internet, it was also established that the willingness to connect is not defined by the time a node joins the system but its “fitness” for connection from the perspective of the elements to be linked to it. This is known as “the winner takes all” and a good example of it is the late rise but extreme success of Google in comparison with other search engines. This principle explains how certain nodes in a network may have an extremely high connectedness.

Barabási and his team conducted an interesting experiment with scale independent networks. They randomly removed nodes from a network and then examined the coherence of what remained. They found that scale independent networks are resistant to random failures. However, as the system is not homogenous, targeted attacks on selected nodes with a high connectedness results in the disintegration of the entire network.

Nodes with a central function also play a role in another case. Though Barabási and his colleagues used Internet viruses as illustrations, the spread of other phenomena such as advertisements is also a good example (Facebook wishes to take steps against the unlimited circulation of fake news in the social network [4]). If we wish to disseminate something in the system, we should start at the central nodes. The same applies to preventing the circulation of a piece of information.

It is important to be familiar with the characteristics of scale independent networks – for example, their strengths, weaknesses, and behaviour – as networks with more or less identical structures will be similar, regardless of the differences in their content. Knowing the behaviour of one system, we may predict that of another.

Network characteristics

When we are familiar with the characteristics of scale independent networks, we may decide whether the network we are studying belongs to this category or not.

Fig. 1 shows a random network that complies with the Erdős-Rényi principles. Visualizing only a few nodes and edges already results in a confusing pattern where the groups of nodes with a high or low connectedness are difficult to identify, if their identification is possible at all.

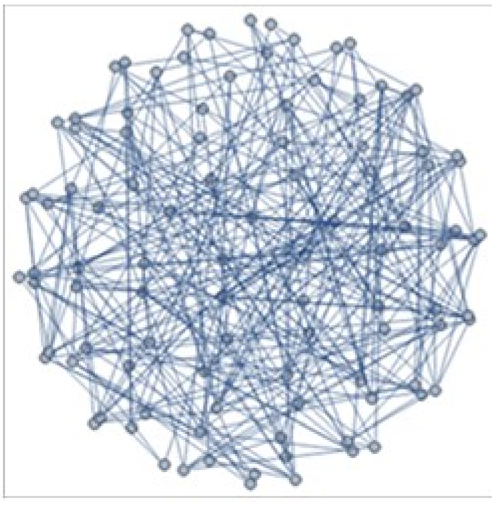

Fig. 1. Random network

Histograms (see Fig. 2) provide much more information. The degree distribution of the examined graphs may be read on the horizontal axis of the diagram (from left to right), while the vertical axis gives the number of the relevant nodes. In Fig. 2 we can see, for example, that in the examined network there are five nodes with 3 degrees (neighbours) and nineteen nodes with 7 degrees. It is also important to consider the shape of the histogram. In this particular case we can see that most nodes are connected to nineteen edges in the system and there is no single node with an extremely high number of connections.

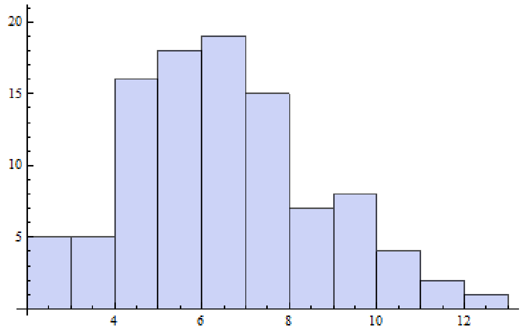

Fig. 2. Degree distribution of a random network

The graph of a network in the Barabási model (Fig. 3) appears to be quite similar to that in Fig. 1. However, its histogram (Fig. 4) indicates a radically different pattern of behaviour.

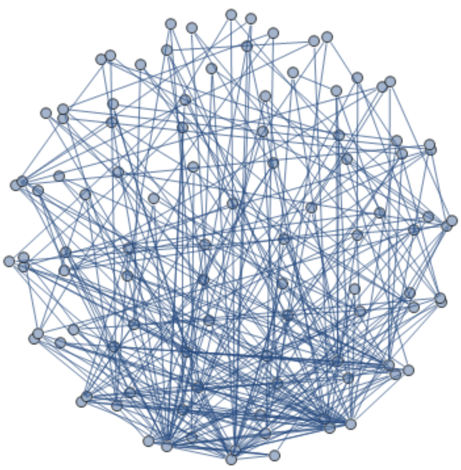

Fig. 3. Scale independent network

Most nodes have only a low connectedness (five or fewer connections) and the number of highly connected nodes decreases rapidly. However, moving along the horizontal axis to the right, we can still find one or two nodes with very high degrees.

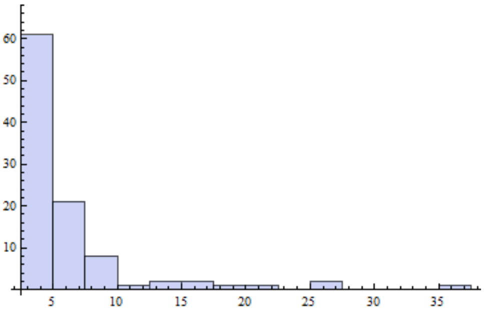

Fig. 4. Degree distribution of a scale independent network

Examining Geographical Networks

In education, networks are mostly examined at the level of sociometric surveys, although the assessment of other systems could also yield important results. From the various levels presented in education, we selected a geographical network as the subject of our examination.

The training programme for public education managers of the Budapest University of Technology and Economics is an adult education course that has its centre in Budapest while offering opportunities for consultation in several other towns in Hungary. The network is built up of geographical locations (nodes) while connections (edges) are represented by pathways that start from Budapest and provide for the spreading of educational content and pedagogy.

Now that we have defined our geographical network, let's see how it looks. Fig. 5 shows the settlements in Hungary where the students live and work, i.e. the locations where the content of the training course will eventually arrive, travelling in the minds of the students in the form of thoughts and elements of knowledge.

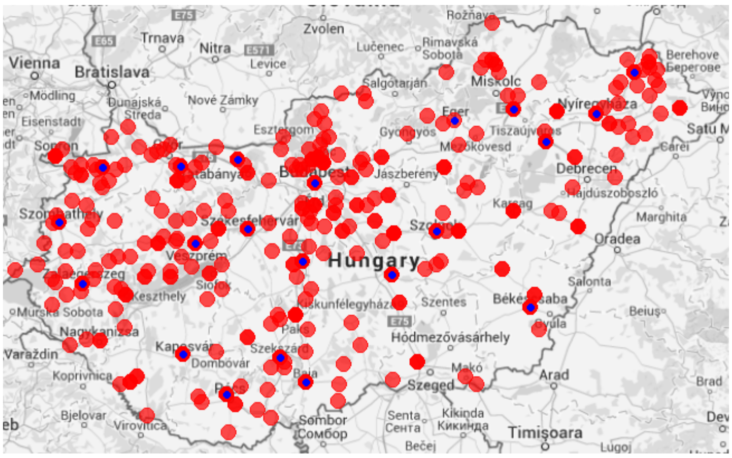

Fig. 5. Home towns of students (red)

and consultation centres(blue)

Fig. 6 illustrates the two levels of the geographical network. Light blue indicates the connections between consultation centres, while dark blue signifies the links between students and consultation centres. In the figure, we can see the locations visited by the students as well as the spread of “knowledge packages” throughout the country, starting from the Budapest centre.

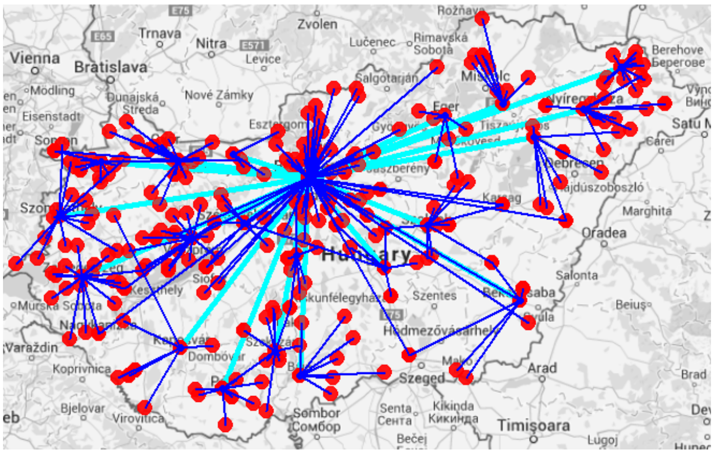

Fig. 6. Levels of geographical networks

In Fig. 7, we attempt to visualize the distances that would be travelled by students if the content of the programme was only available in Budapest. The average distance to be travelled by a student in such a scenario would be 106.8 km; when local consultation centres are also used, the distance is only 19.7 km. Calculating with an average fuel price of HUF 400/l and a consumption of 8 litres per 100 km, a student would spend HUF 3420 on travelling in the first scenario and HUF 630 in the second. If we assume an average speed of 60 km/h, travelling would take an average of 1.8 hours when only the Budapest centre was available for training and 0.3 hours in the case of local centres. Extreme values do stand out of course; for example in the first scenario a student living particularly far from Budapest would be required to travel 265 km (4.4 hours) to participate on the course.
Providing for the comfort of students is not a *l’art pour l’art* initiative. Students who need to travel less can focus more on their studies. We should also consider the fact that decentralized education may be of higher quality, as participants not burdened by the strains of travelling can be loaded with more information.

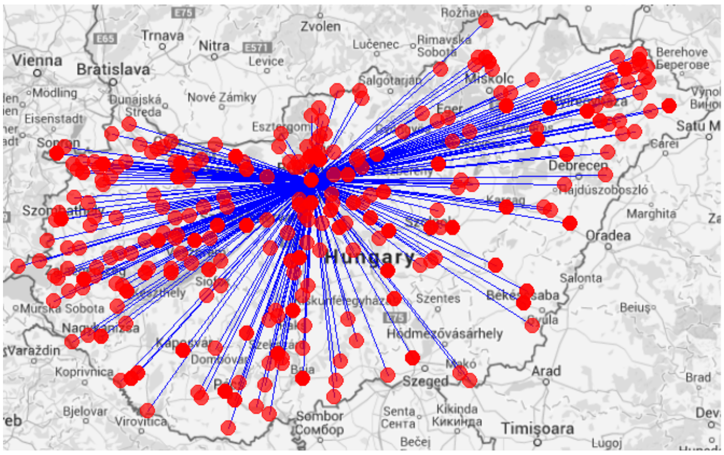

Fig. 7. Centralized network with its centre in Budapest

The mathematical analysis of this geographical network provides even more details. Fig. 8 shows the examined network as a graph. The average degree has been established as 2.15. The structure of the network can be clearly distinguished: the centre (Budapest) is connected to each local consultation centre and also serves as one itself, while additionally being connected to the home towns of the students. Local consultation centres are also highly connected. The home towns of the students, on the other hand, rarely have more than one connection (the reason for this is that students from the same town could choose from several local consultation centres and travel to these places along different routes).

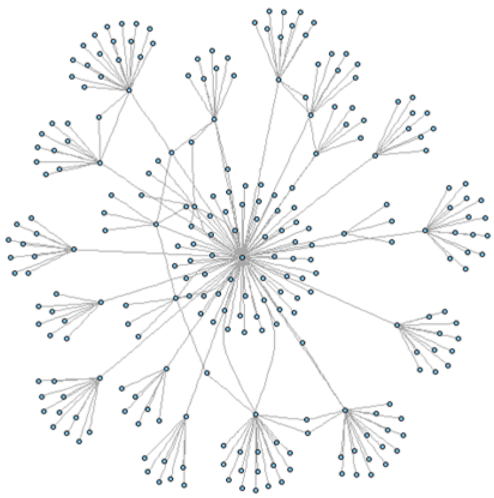

Fig. 8. Geographical network vizualised as a graph

Degree distribution is given by the histogram in Fig. 9. Note the unique shape of the histogram.

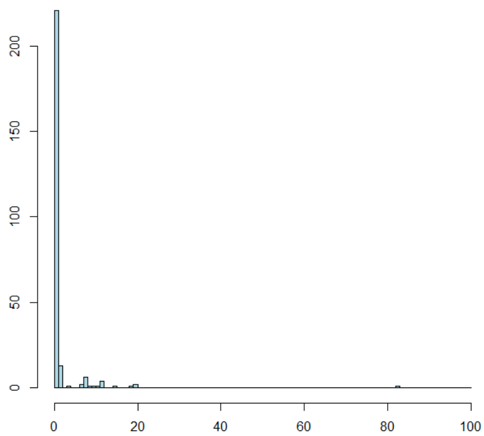

Fig. 9. Degree distribution of the geographical network

In addition to the central node with its eighty-three connections, the network includes numerous (about 221) nodes with one connection only.
We generated an Erdős-Rényi random graph with 245 nodes and 275 edges. This graph has the same number of nodes and edges as the examined geographical network, but differs from it regarding its internal building forces. We attempted to highlight this difference by mathematical analysis.

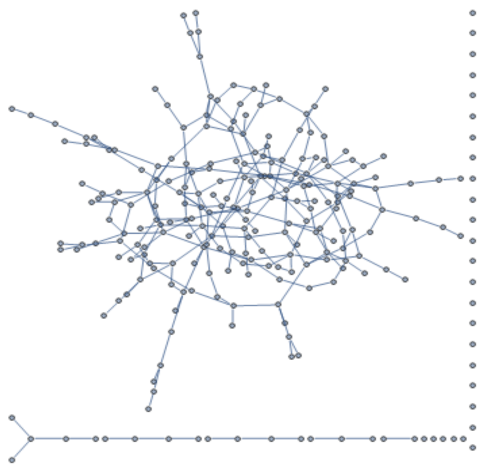

Fig. 10. Random graph with 254 nodes and 275 edges

The average degree of the nodes of the graph in Fig. 10 is 2.16. As can be clearly seen when examining the largest coherent section with an average degree of 2.5, this graph also includes unconnected nodes. Fig. 11 shows the degree distribution of the nodes of the original random graph. As illustrated by the figure, the majority of nodes are connected to three others, while a relatively small number of nodes have very few or very many connections.

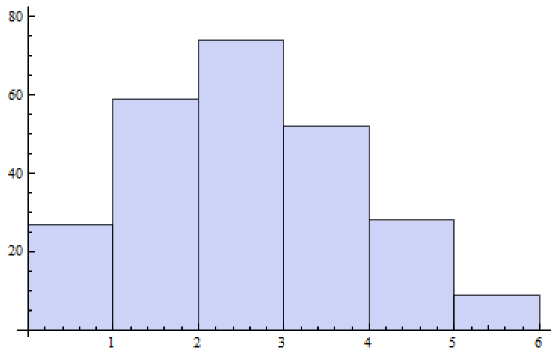

Fig. 11. Degree distribution of the random graph

Fig. 12 shows a network which is quite similar to the examined geographical network, but which is scale independent. As we can see in Fig. 13, there is a node on the right-hand side of the distribution curve with a degree of 25, while the number of nodes with only one degree is 170. This graph is entirely coherent, with an average degree of 1.99.

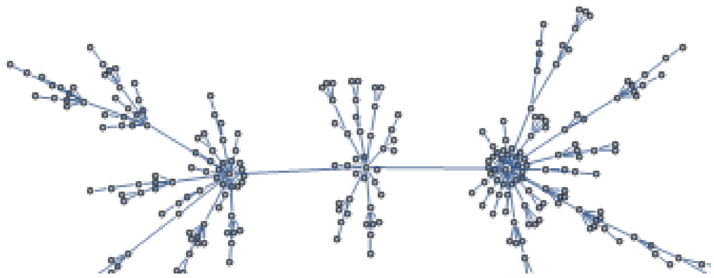

Fig. 12. Scale independent network with 254 nodes and 253 edges

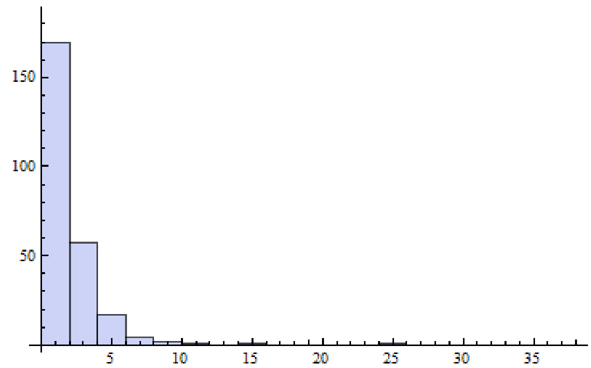

Fig. 13. Degree distribution of the nodes of the scale independent network

The histogram of the geographical network is similar in shape to the Barabási scale independent system. In addition to the large number of nodes with only a few connections, there are also some nodes with high degree values (though only one or two) featuring large empty sections between them when moving along the horizontal axis to the right, while the histogram of the random graph does not have such "remote sections".

In our case, this means that the characteristics of the network resemble those of a scale independent system. The presence of a central node (Budapest) also indicates this. Although the structure of the examined geographical network is not overly complex, it has a large number of elements. It is not uncommon in training practice that a few consultation locations cease to operate during the programme; despite this, the system itself will remain functional. In this respect, it resembles the robustness of scale independent networks. The central node, however, plays an essential role. If it is removed, the network disintegrates – which is also a trait of scale independent systems.

Future prospects

We examined an existing, functional education system, identifying the related geographical network. We found the system to be very similar to scale independent networks, showing both their positive characteristics and their drawbacks. The current geographical structure of the aforementioned training programme for adult education managers has been developed over a long period of time, although this type of geographical outsourcing was applied from its inception.

Such decentralized operation has quantifiable advantages. Students' travelling costs are reduced, as they are able to visit local centres instead of having to travel to Budapest. Another, indirect, benefit of the system is that participants are more relaxed and receptive during the consultations than they would be if the entire training programme took place in Budapest. In the latter case, the organizers would also face a serious challenge, as it would be virtually impossible to find a venue that could host several thousand people and also because communication with so many participants would be an extremely difficult task.

Analysing networks in the fields of both education and adult education has great potentials. Interesting results are to be expected from the analysis of other network components of education (infometrics, sociometrics, etc.), too.

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