

cant investments in network and systems medicine, seeing it as the path towards future drugs.

Security: Fighting Terrorism.

Terrorism is one of the maladies of the 21st century, absorbing significant resources to combat it worldwide. Network thinking is increasingly present in the arsenal of various law enforcement agencies in charge of limiting terrorist activities. It is used to disrupt the financial network of terrorist organizations, to map terrorist networks, and to uncover the role of their members and their capabilities. While much of the work in this area is classified, several success stories have surfaced. Examples include the use of social networks to capture Saddam Hussein or the capture of the individuals behind the March 11, 2004 Madrid train bombings through the examination of the mobile call network. Network concepts have impacted military doctrine as well, leading to the concept of net-war, aimed at fighting low intensity conflicts and crime waged by terrorist and criminal networks that employ decentralized flexible network structures [13]. One of the first network science programs at the college level was started at West Point, the US Army's military academy. In 2009 the Army Research Lab and the Department of Defense devoted over \$300 million to support network science centers across the US.

Epidemics: From forecasting to halting deadly viruses.

While the H1N1 pandemic was not as devastating as it was feared at the beginning of the outbreak in 2009, it gained



Image 1.9
Predicting the H1N1 epidemic.

The predicted spread of the H1N1 epidemics during 2009, representing the first successful prediction of a pandemic. The project, relying on the details of the worldwide transportation networks, foresee that H1N1 will peak out in October 2009, in contrast with the normal January-February peaks of influenza. This meant that the vaccines planned for November 2009 were too late, which was indeed the case. The success of this project shows the power of network science in facilitating advances in areas affected by networks.

Movie by D.Balcom, B.Gonçalves, H.Hu, and A.Vespignani.

a special role in the history of epidemics: it was the first pandemic whose course and time evolution was accurately predicted months before the pandemic reached its peak (Image 1.9) [14]. This was possible thanks to fundamental advances in understanding the role of networks in the spread of viruses. Indeed, before 2000 epidemic modeling was dominated by compartment models, assuming that everyone can infect everyone else one word the same socio-physical compartment. The emergence of a network-based framework has fundamentally changed this, offering a new level of predictability in epidemic phenomena.

Today epidemic prediction is one of the most active applications of network science [15, 16]. It is the source several fundamental results, covered in this book, that are used to predict the spread of both biological and electronic viruses. The impact of these advances are felt beyond biological viruses. In January 2010 network science tools have predicted the conditions necessary for the emergence of viruses spreading through mobile phones [17]. The first major mobile epidemic outbreak that started in the fall of 2010 in China, infecting over 300,000 phones each day, closely followed the predicted scenario.

Brain Research: Mapping neural network.

The human brain, consisting of hundreds of billions of interlinked neurons, is one of the least understood networks from the perspective of network science. The reason is simple: we lack maps telling us which neurons link to each other. The only fully mapped neural map available for research is that of the *C.Elegans* worm, with only 300 neurons. Should detailed maps of mammalian brains become available, brain research could become the most prolific application area of network science. Driven by the potential impact of such maps, in 2010 the National Institutes of Health has initiated the *Connectome* project, aimed at developing the technologies that could provide an accurate neuron-level map of mammalian brains.

Management: Uncovering the internal structure of an organization.

While traditionally management uses the official chain of command to understand the inner structure of an organization, it is increasingly evident that the informal network, capturing who really communicates with whom, matters even more for the success of a company. Accurate maps of this network can expose lack of communication between key units, can identify individuals who play an outsize role in bringing different departments and products together,

and help higher management diagnose diverse organizational issues. Furthermore, there is increasing evidence in the management literature that the position of an employee within this network correlates with his/her productivity [18].

Therefore, several dozen consulting companies have emerged with expertise to map out the true structure of an organization. Established consulting firms, from *IBM* to *SAP*, have added social networking capabilities to their consulting business. These companies offer a host of ser-

vices, from identifying opinion leaders to preventing employee churn and from identifying optimal groups for a task to modeling product diffusion (Image 1.10a/b/c/d). Hence lately network science tools are increasingly indispensable in management and business, enhancing productivity and boosting innovation within an organization.

Network science can therefore offer a microscope for higher management, helping them improve the company's effectiveness by uncovering the true network behind any organization.

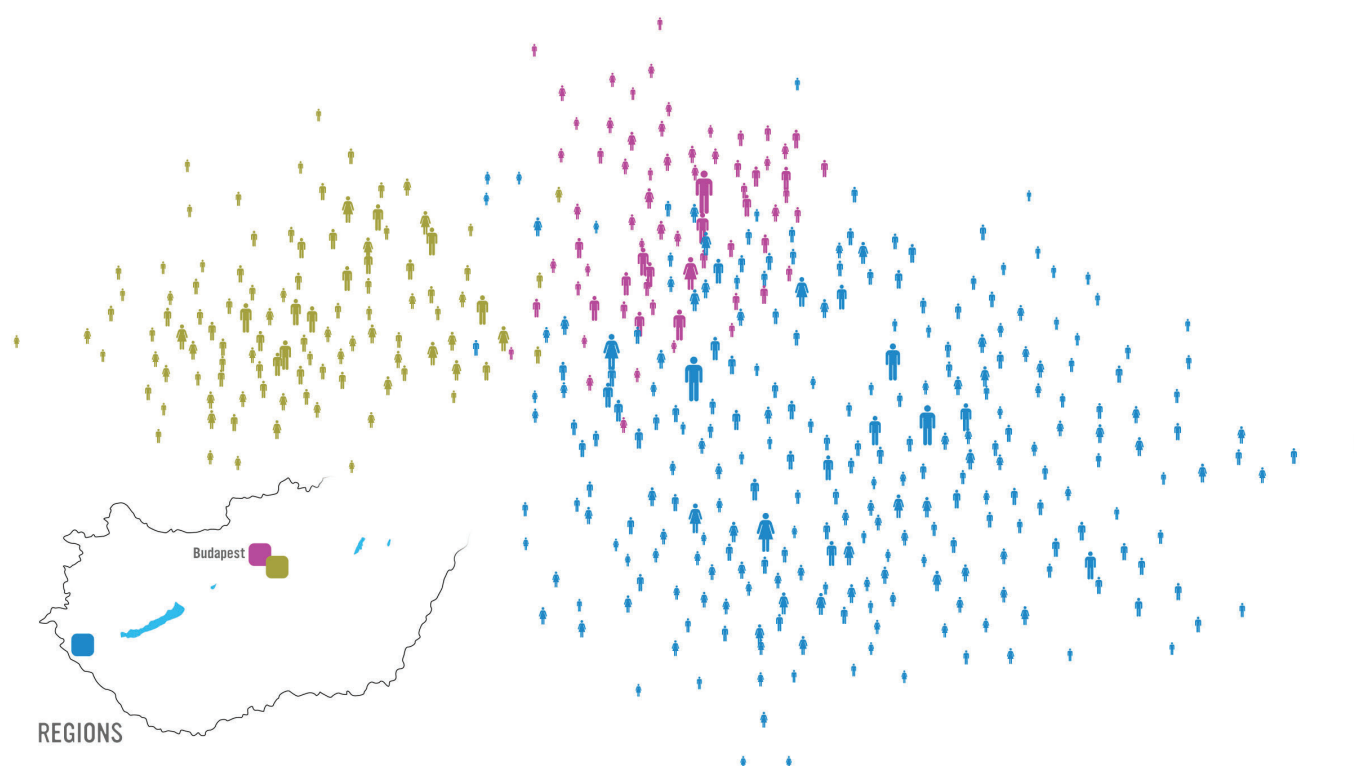


Image 1.10a

Understanding the inner workings of an organization.

The workforce of a Hungarian company with three main locations, one on Budapest, whose employees are shown in purple, and two manufacturing sites outside of the city, shown in yellow and blue. The company had a major internal communication problem: information that reached the workers about the intentions of the higher management often had nothing to do with the management's real plans. Seeking to understand the source of this discrepancy, and looking for ways to embrace information flow within the company, the management turned to Maven 7, a social networking consulting company that applies network science in diverse organizational setting.

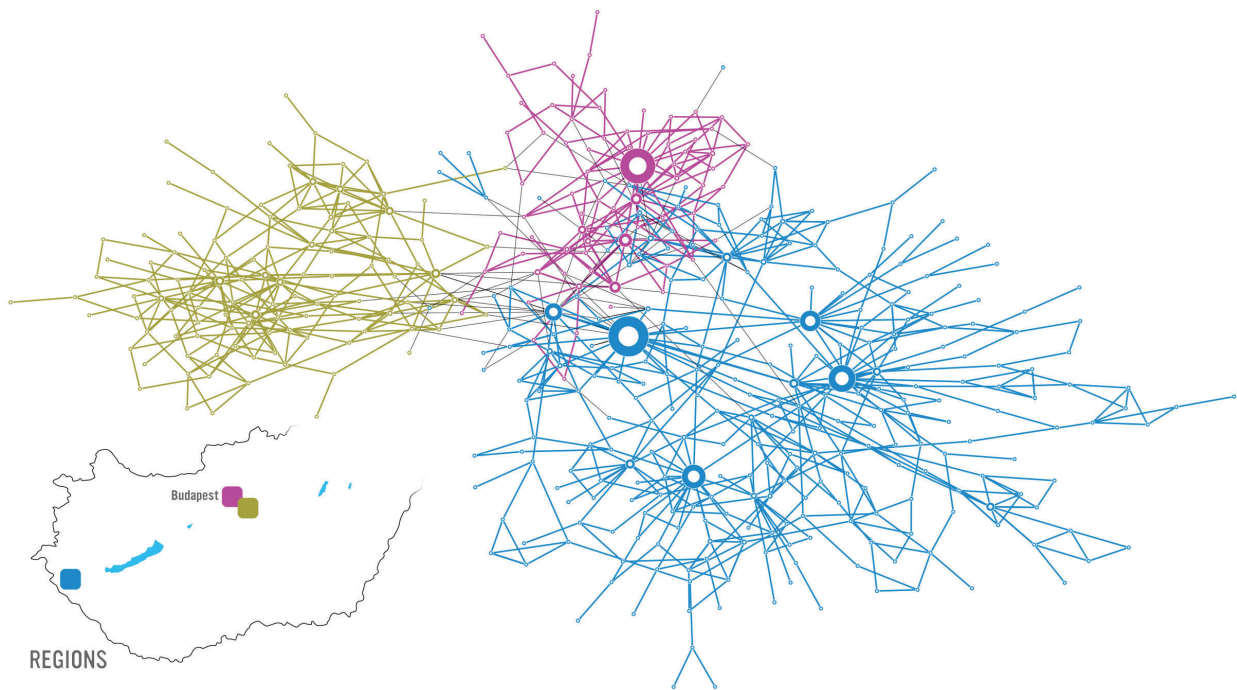


Image 1.10b

Understanding the inner workings of an organization.

Having the list of the workers and their role in the company, together with the official hierarchy is not sufficient to understand how an organization works. For that we need to know who listens to whom, who is asking for advice from whom, eventually uncovering the paths through which knowledge and information travels within the organization. Hence Maven 7 developed an online platform to ask each employee whom do they turn to for advice when it comes to decisions impacting the company, from restructuring to advancement. This allowed them to build the map shown above, where two individuals are connected if one nominated the other as his/her source of information on organizational and professional issues.

The map identifies several highly influential individuals that are the hubs of the organization. The problem was that none of the hubs were part of the leadership.



Image 1.10c

Understanding the inner workings of an organization.

The position of the leadership within the company's informal network is illustrated on this map, where we colored the nodes based on their company rank within the company. None of the company directors, including the CEO, shown in red, are hubs. Nor are the top managers, shown in blue. The hubs are managers, group leaders and associates, or workers. The biggest hub, hence the most influential individual, is an associate, shown as a gray node in the center.



Image 1.10d

Understanding the inner workings of an organization.

The image indicates that a significant fraction of employees are one to two links from the biggest hub. It turns out that he is the safety and environmental expert in the company, whose job is to visit each location and talk with most employees. There is only one part of the company he has no links to: the directors or the top management. With little access to the management and their intentions, he passes on information that he collects along his trail, effectively running a gossip center.

How does one remedy this situation? Fire the biggest hub? He is not the problem and firing him would probably make the problem even more acute. The real issue is that higher management failed to put in place proper channels of communication, leaving behind a structural hole, which was naturally filled by the environmental and safety manager. Offering him and the few other hubs access to the true information can fundamentally change the reliability of information within the company. Network science can therefore offer a potent microscope for higher management, helping them improve the company's effectiveness by uncovering the true network behind an organization.