Book Review of:
"Network Science" (by Albert-László Barabási)

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Abstract

This book review has been written and prepared for the SIAM Activity Group on Dynamical Systems and the associated community page `https://dsweb.siam.org/`. It has appeared in the TODO issue of DSweb.

Before I enter into a more detailed review, let me briefly explain, why I found the book "Network Science" by Albert-László Barabási particularly intriguing for a review. The topic of networks has picked up considerable interest during the last twenty years in various sciences. Barabási is undoubtedly a pioneer in this regard, who has fostered new developments since the surge of networks began. He is also a co-author of one of the most cited reviews (with Reka Albert) [1]. This review, in tandem with the review by Newman [6], more or less defined the groundworks for a decade of networks research. Some other pioneers, such as Newman [7], Kleinberg [4] and Vespignani [2], have written or collaborated on textbooks but there is definitely still a need to have additional sources. In this regard, one should also mention that Barabási has been supported by an entire research team in the prepration of this book and I shall mention Márton Pósfai explicitly here, who is credited in the book with the responsibility for "calculations, simulations and measurements".

So what is the target, and the target audience, of Barabasi's most recent take on the subject? The first important point to note is that "Network Science" is first and foremost a *textbook*. From the introduction it is evident that the goal of classroom use was a design principle. More precisely, a course taught by Barabási for upper-level undergraduates and beginning graduates in physics, computer science and engineering forms the main thread of the book. The book includes very nice homework exercises as well as a detailed strategy for a final student project. The goal of the project is to determine, sample, and analyze a real network. This type of project already hints at the core idea to synergize network theory to data analysis. In fact, this link (no pun intended) between real-world data sets and deceptively simple theoretical models was a key reason, why the modern version of network science has revitalized the existing classical analysis of random graphs from the 1950s and 1960s. Barabasi's book reflects this development in an excellent fashion.

The book has ten chapters. Although this grouping might be very simplistic, essentially the chapters 2-9 revolve around the *structure* of networks. This is highlighted by the central discussion of the power-law of many networks in chapter 4. More precisely, the probability

p_k to find a node of degree k in the network is given by $p_k \sim k^{-\gamma}$ for some exponent γ. This theme is always compared to classical random graphs, ala Erdös-Rényi, which follow a binomial (or limiting Poisson) degree distribution. Barabási uses the comparison in a wide variety of ways to explain other key discoveries such as the existence of hubs, path-lengths/small-world properties, network growth models, fault and attack tolerance, community structure, and so on. The gradual development and careful presentation of the network structure theme is very accessible, yet conveys many deep insights found during the last twenty years. Therefore, anybody interested in learning this topic from the ground up - with almost no pre-requisities required - should definitely consider reading Barabási's book, or use it as a course text.

It is also important to mention that the book has many interesting features, which distinguish it from other, more traditional, textbooks. It is very far away from the classical 'definition, lemma, proof, theorem, proof, corollary'-style common for mathematics texts. This is quite clear since it is not primarily intended for this audience. However, even from the viewpoint of physics and engineering, it has many relatively uncommon approaches. The layout mainly proceeds along four columns. The two inner columns contain the main text. The outer two columns, sometimes even more, are used for figures, remarks, summary boxes, data sets, visualization, links to online resources, etc. Also the personal introduction by Barabási is a very interesting read, and I won't say more about it here to not spoil the first encounter with the preface. Another important point is that the book is available freely online: `http://barabasi.com/networksciencebook/`

Each chapter is followed by 'Advanced Topics', which basically discuss some of the calculations to derive many mathematical formulas and statements. This appendix-style is also used to deepen several discussions, which cannot find their way into the main text. In some sense, this appendix-style certainly helps to bridge the backgrounds of diverse audiences quite a bit and it is easier to distinguish the main application ideas from the mathematical theory. This is certainly a possible innovative approach to make the book useful for transdisciplinary courses. My personal recommendation would be that for a mathematically-oriented course, one can bring in most advanced topics, or even augment the arguments by ideas grounded in theoretical probability from the textbook of Durrett [3] or the recent monograph of van der Hofstad [8].

Since this review has been prepared for the community in dynamical systems, let me comment on aspects related to dynamics. The last part of the book, chapter 10, is probably closest to dynamics. It discusses epidemic spreading and how the structure of the network influences the location of the epidemic threshold. In particular, one may make the epidemic threshold move quite a bit, or even disappear in a limit, when random graphs are replaced by power-law degree distributions. In this context, also a possible mean-field approximation for various susceptible-infected dynamics and its variants is sketched. Of course, we are very far away from a deep understanding of dynamical processes *on and of* networks [5], so it may actually be a wise decision at this stage by Barabási to not include an in-depth look at dynamics in a first course. However, it would certainly be more than welcome - at least in my personal opinion - that the applied dynamics community should think about writing one, if not more than one, sequel to the books mentioned in the references as well as the book by Barabási to present the fundamentals of dynamics for network science.

In summary, I can highly recommend Baraási's book for anyone looking to teach an interdisciplinary course on networks or anyone aiming to learn the basics of network structure with a view towards applications. Personally, I intend to use it as a source for undergraduate seminars for mathematics students to introduce them to the topic by self-study. Hopefully then, the book is going to set out the exploration path for them to acquire and invent new mathematical methods. As another personal note, let me stress that the field is moving so rapidly, that it seems useful to take stock once in a while. From a mathematical perspective, carefully preparing and categorizing recent developments in a more accessible form is beneficial at the time this book review is written. Hence, Barabási sets out with his textbook an agenda that hopefully many others are going to follow soon.

References

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