A Guide to the CDTs (CDT-0)

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A Guide to the CDTs
(CDT-0)

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Abstract

A brief guide to the whole series of CDTs is provided, including tables with their complete listing and respective hyperlinks and main areas, as well as some suggested study programs combining several CDTs as a means to become familiarized, or to review, some areas including basic mathematical concepts and methods, statistics, pattern recognition, signal processing, image analysis, scientific modeling, network science, as well as sound and music. Some basic scientometric statistics are also provided with the respective number of reads, recommendations and RG Index of the CDTs, as well as their pairwise correlation.

"..., teach, learn, understand, create, teach, learn, ..."

LdFC.

1 Introduction

The CDT (Costa's Didactic Texts) series was initiated in April 2018, being primarily aimed at providing a relatively self-contained and brief introduction to topics related to the author's didactic activities and research interests.

More specifically, CDTs intend to be a halfway point between a formal scientific article and a dissemination text in the sense that they: (i) explain and illustrate concepts in a more informal, graphical and accessible way than the typical scientific article; and (ii) provide more in-depth mathematical developments than a more traditional dissemination work. Typically, the material in the CDTs can be read in a relatively short period of time, or constitute the subject of approximately one or two learning sections of 2 o r 3 hours each, depending on the previous background of the readers.

In addition, it is hoped that CDTs can also incorporate new insights and analogies concerning the reported concepts and methods. We therefore hope these characteristics will contribute to making CDTs interesting both to beginners as well as to more senior researchers from complementary areas or who want to refresh their knowledge respectively to the covered subjects.

Since their introduction, CDTs have covered several topics in the areas of network sciences, complex systems, scientific modeling, mathematical concepts and methods, signal processing, pattern recognition, artificial intelligence, programming, image and shape analysis, electronics, and music. Though addressing different areas, CDTs are well integrated one another, and therefore can be used to complement one another.

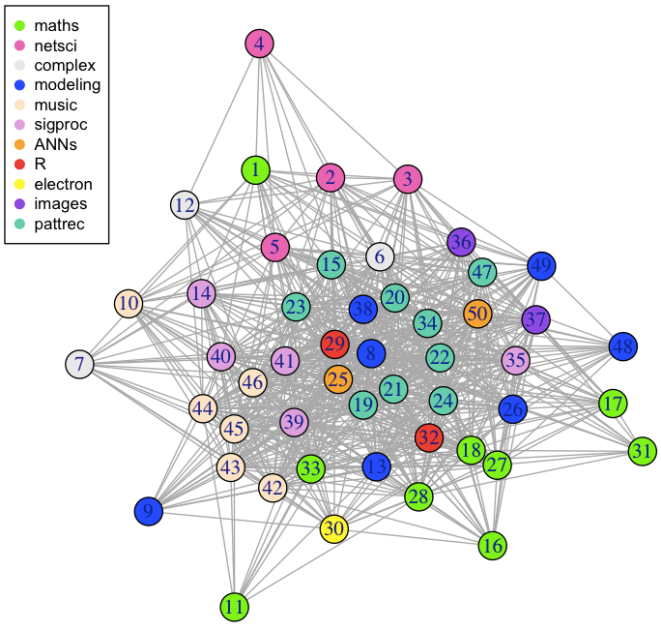

Figure 1: Graph representing each of the 50 CDTs as a node, while the links represent strong relationships. The average node degree($\pm st.dev.$) is 29.04($\pm$9.18).

Now incorporating 50 titles, it has become possible to consider combinations of CDT titles as part of a reading program covering a larger body of knowledge.

The present text aims at providing a listing of all CDTs, with respective pointers, as well as suggesting some possible study programs in some more directly related areas. It should be kept in mind that these suggestions are preliminary and tentative, in the sense that each reader, motivated by each specific objectives and with specific previous background, may prefer to follow other sequences more suited to each situation. However, it is hoped that the suggested programs provide some idea of the many relationships and interdependences between the several CDT titles. In case the reader uses the R environment, some basic support to the implementation of many topics in the CDTs are provided in CDT-29 and CDT-32.

In addition, some basic scientometric statistics are also provided regarding the number of reads, recommendations and the ResearchGate Index.

2 The Whole List of CDTs

Tables 1 and 2 presents the complete list of titles in the CDT series, their titles (hyperlinked to the respective CDTs), as well as the dominating area. Observe, however, that every CDT is related to more than one area.

3 Study Program 1: Mathematical Concepts and Methods

As a general preparation to better understanding the CDT titles, and also as a possible means to refresh respective concepts, it would be interesting to start with CDT-1, which will provide basic concepts in linear algebra of matrices and respective products, proceeding to the subject of curve fitting in CDT-17 as well as a revision of multivariate calculus in CDT-27. At this point, it may be interesting to review concepts of ordinary differential equations through their visualization in CDT-16, possibly followed by a study of partial differential equations in CDT-21. The interesting issue of function minimization and optimization can then be studied in CDT-18. The relatively more advanced concepts of eigenvalues/eigenvectors (CDT-28), Lagrange multipliers (CDT-31) and group theory (CDT-11) could then be approached.

4 Study Program 2: Statistics

A brief review of statistics, which is especially recommended as a preparation for reading CDT titles related to pattern recognition, AI and Scientific modeling, may involve starting with basic univariate statistical concepts in CDT-13, followed by a subsequent continuation with multivariate statistics covered in CDT-26, and then reading about principal component analysis in CDT-47.

5 Study Program 3: Pattern Recognition and AI

After revising basic statistical concepts as suggested in Section 4, it may be interesting to study CDT-19 for an introduction to pattern recognition, followed by complementary discussion of the relationship between features and categories provided in CDT-20. CDT-22 may be read subsequently in order to better understand how simple patterns can be created, followed by a CDT-23, which describes several measurements that can be used to characterized one-dimensional signals. CDT-24 can then be read in order to get familiarized with concepts and methods of feature normalization and applications in pattern recognition, which can be complemented by the brief introduction to PCA provided in CDT-47. CDT-34, which describes the important methodology known as Bayesian classification may be read in continuation, as well as CDT-25, which discusses how neurons perform patter recognition, including self-organizing neuronal networks, while the interesting Hopfield artificial neuronal network models is introduced in CDT-50. The more advanced subject of deep learning may then be approached in CDT-15.

6 Study Program 4: Signal Processing

In addition to its intrinsic interest, the area of signal also provides a valuable background for better understanding many other CDTs and involved areas. An introduction/review to signal processing may start with the programs suggested in Sections 3 and 4, especially in case the reader has little previous experience in these areas. Then, CDT-14 may be approached, covering some basic concepts in Fourier transform, convolution, and linear dynamic systems. This introductory text may be subsequently complemented by CDT-39, which discusses the problems involves while translating signals from the analog to digital realms, and vice-versa. The directly related issue of enhancing the accuracy of the Fourier transform is addressed in CDT-41. At this point, the reader may consider extending further to the concept of instantaneous signal analysis by reading CDT-40, followed by complementations and applications to sound synthesis and music in CDT-42, CDT-43, and CDT-44. The study of signal processing may also incorporate CDT-7, about phasors,

Table 1: CDTs from 0 to 25.

CDT	*Title (hyperlink)*	*Main Area*
CDT-0	A Guide to the CDTs (this work)	Guide
CDT-1	Matrix Products, Complex Networks, Diffusion: Anything in Common?	Maths
CDT-2	What is a Complex Network?	NetSci
CDT-3	Spatial Networks: When Topology Meets Geometry	NetSci
CDT-4	Text Networks	NetSci
CDT-5	Visualizing Complex Networks	NetSci
CDT-6	Quantifying Complexity	Complexity
CDT-7	Circuits, Oscillations, and the Kuramoto Model as Visualized by Phasors	Complexity
CDT-8	Modeling: The Human Approach to Science	Modeling
CDT-9	The Laplace Transform in a Nutshel	Modeling
CDT-10	Modeling Consonance and Its Relationships with Temperament and Harmony	Music
CDT-11	Group Theory: A Primer	Maths
CDT-12	Creativity and Complexity	Complexity
CDT-13	Statistical Modeling	Modeling
CDT-14	Convolution!	SignProc
CDT-15	Learning Deep Learning	PattRec
CDT-16	Visualizing the 'Content' of Differential Equations	Maths
CDT-17	Linear Least Squares: Versatile Curve and Surface Fitting	Maths
CDT-18	Down the Road to Minimization	Maths
CDT-19	Pattern Cognition, Pattern Recognition	PattRec
CDT-20	On Features and Categories	PattRec
CDT-21	Pattern Formation: Modeling Space-Time Dynamics	PattRec
CDT-22	Where Do Patterns To Be Recognized Come From?	PattRec
CDT-23	Discrete One-Dimensional Signals: A Brief Catalogue of Features	PattRec
CDT-24	Features Transformation and Normalization: A Visual Approach	PattRec
CDT-25	Neurons as Pattern Recognizers	ANNs

as well as CDT-33, about the important issue of representing and estimating phase from periodical signals.

7 Study Program 5: Image and Shape Analysis

Directly related to the areas of image processing and vision, the subject of image and shape analysis involves several interesting concepts and methods that can be applied

Table 2: CDTs from 26 to 50.

CDT	*Title (hyperlink)*	*Main Areas*
CDT-26	Multivariate Statistical Modeling	Modeling
CDT-27	A Mosaic of Multivariate Calculus	Maths
CDT-28	Eigenvalues and Eigenvectors	Maths
CDT-29	An Abridged Introduction to R	R
CDT-30	Visual Electronics: Graphic Analysis of Circuits	Electronics
CDT-31	⟵ Lagrange Multipliers . Multiple Applications ⟶	Maths
CDT-32	The R in gRaphics	R
CDT-33	..., Sine, Cosine, Periodicity, Phase, Sine, ...	Maths
CDT-34	Bayesian Classification	PattRec
CDT-35	What Can Curvature Tell us About Shape?	SignProc
CDT-36	Principles of Image Formation in Nature and Machine	Images
CDT-37	When Less is More: Detecting Edges in Images	Images
CDT-38	A Synthetic Introduction to the Genetic Algorithm	Modeling
CDT-39	Signals: From Analog to Digital, and Back	SignProc
CDT-40	Instantaneous Signal Analysis	SignProc
CDT-41	An Almost Continuous Discrete Fourier Transform	SignProc
CDT-42	On Sound Synthesis I: Single Note, Single Frequency	Music
CDT-43	On Sound Synthesis II: Single Note, Varying Frequency	Music
CDT-44	On Sound Synthesis III: Single Note, Multiple Frequencies	Music
CDT-45	On Sound Synthesis IV: Rhythm and Tempo	Music
CDT-46	On Sound Synthesis V: Tonality and Melody	Music
CDT-47	A Compact Guide to PCA	PattRec
CDT-48	Build your Own [Virtual] Microprocessor	Modeling
CDT-49	Distributed Systems through a Simple Interpreter	Modeling
CDT-50	A Compact Guide to The Hopfield Network	ANNs

to a large number of situations. After possibly following the programs of study in Sections 3, 4, 5, and 6, basic concepts about image formation can be studied in CDT-36, followed by the especially challenging and important subject of edge detection as discussed in CDT-37, as well as the estimation of curvature of two-dimensional shapes presented in CDT-35.

8 Study Program 6: Scientific Modeling

The whole of science directly relies on modeling through the scientific methods. As such, almost every CDT title is somehow related to scientific modeling, either providing respective subsidies, or to covering that subject in a more

directed manner.

CDT-8 constitutes an introduction to scientific modeling that can be mosly read without further preparation. More systematic studies may consider preliminary covering the programs of study in Sections 3, 4, and 5. Given that the main challenges in scientific modeling are subsumed into the elusive concept of complexity, further insights about modeling can be obtained by reading CDT-6, then proceeding to the relationship between complexity and creativity as discussed in CDT-12. Closely related to modeling, by providing subsidies for the solution of differential equations, the Laplace transform, is addressed in CDT-9, which can be read next. A study of CDT-38, covering the genetic algorithm, may also be of interest as an example of mathematical modeling of a biological problem. The possibility to develop models of microprocessors and distributed systems is discussed in CDT-48 and CDT-49, respectively, providing some complementation of modeling as applied to computing, with many possible applications in AI, optimization, design of computing systems, etc. Further complementation of the possibilities of scientific modeling can then be approached through the program of study related to network science, described as follows.

9 Study Program 7: Network Science

Network science, related to the study of complex networks, has become a major and particularly relevant area of current interest as a consequence of the potential that graphs, of which complex networks can be understood as being sophisticated versions, have for modeling virtually every discrete phenomenon, ranging from the Internet to knowledge. Several of the existing CDTs are direct or indirectly related to network science. A possible more direct program of study to this area may involve starting with CDT-1, and progressing to CDT-2 – which discusses what is a complex networks, CDT-3 – which covers a particularly important type of graphs known as spatial networks, CDT-4 – which provides an introduction to networks derived from linguistics, then complementing with the material on CDT-5, about the important problem of properly visualizing complex networks.

10 Study Program 8: Sound and Music

Though it may firstly seem to correspond to a completely different branch of knowledge among the CDT titles, the subject of *sound and music* turns out to be central and closely interrelated to several other titles and covered areas. For instance, several mathematical, statistical, and particularly signal processing concepts and methods can be illustrated and applied to the analysis and synthesis of sound and music. As such, it is recommended to start with the programs os study respectively described in Sections 3, 4 and 6. Having completed this reading, the sequence of CDTs from CDT-42 to CDT-46 may then be studied. The enticing relationship between temperament, harmonic sounds (consonance and dissonance) and network science can then be studied in CDT-10. Another aspect which closely relates sound and music to the CDT titles is the quintessential importance of complexity and creativity, covered in CDT-6 and CDT-12. Equally important is the relationship between sound/music and modeling, therefore emphasizing the connections with CDT-8.

11 Some Scientometric Statistics

The total number of reads, recommendations and RG Index values of each of the CDT titles, as of 4th Jan 2021 are presented in Figure 2.

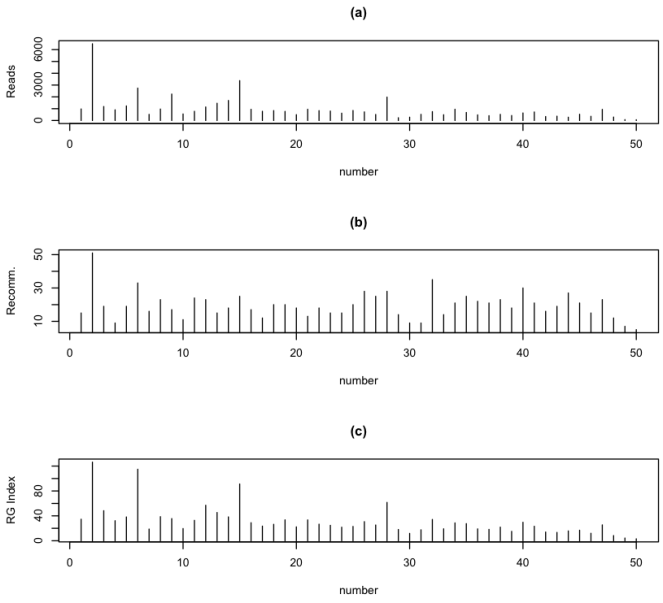

Figure 2: The total number of reads (a), recommendations (b), and RG Index values (c) of each CDT title as of 4th Jan 2021.

The total number of reads is 47,636 and 974 recommendations at the time of writing, which indicate encouraging popularity of the CDT series.

The relationship between the three previous measurements, expressed in terms of respective pairwise scatterplots with respective Pearson correlation coefficients, are depicted in Figure 3.

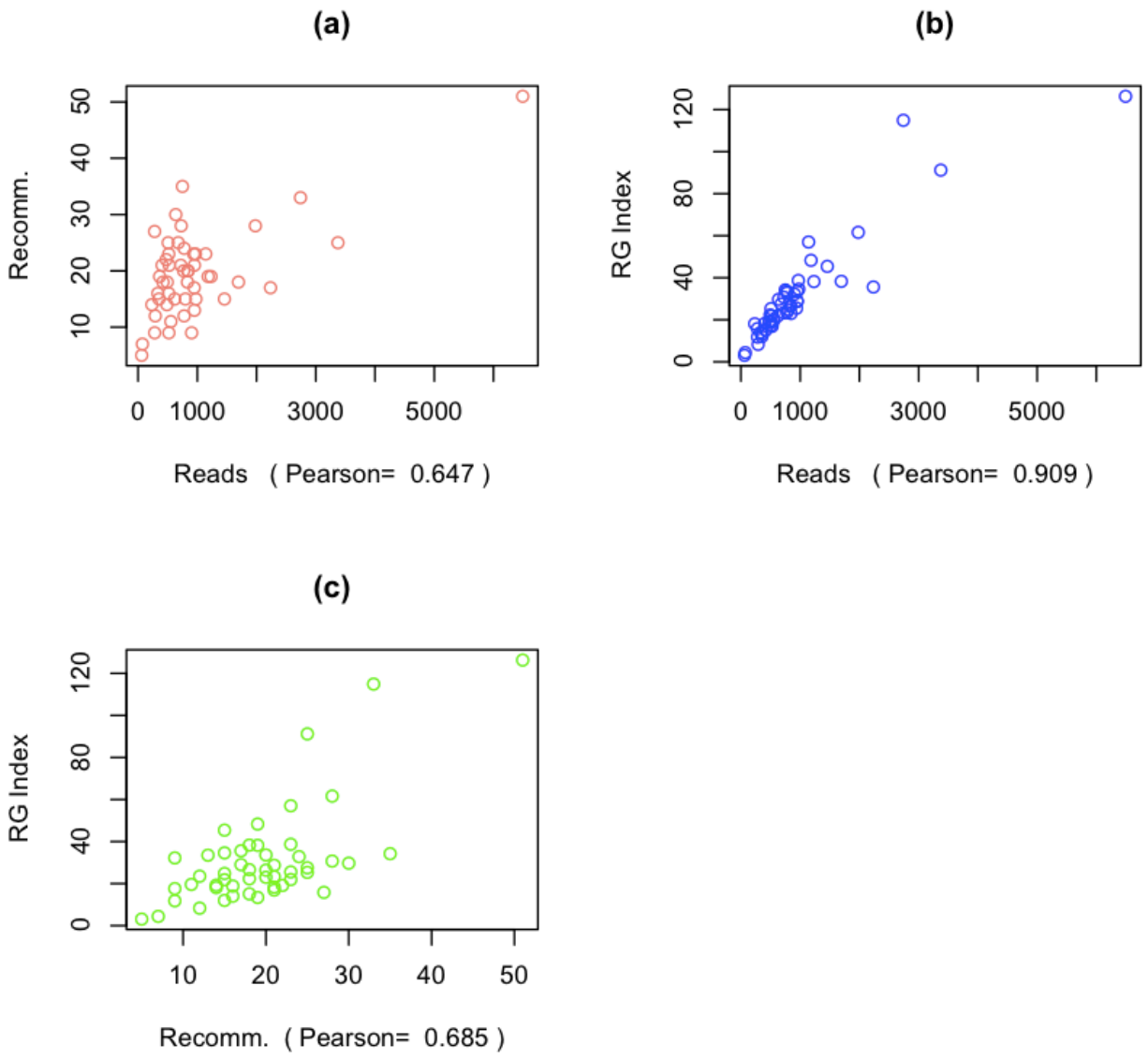

Figure 3: Scatterplots depicting the relationship between Reads and Recommendations (a), Reads and RG Indices (b), as well as Recommendations and RG Indices (c). The respective Pearson correlation coefficients are also provided. As of 4th Jan 2021.

Interestingly, the largest correlation of 0.909 is observed between the number of reads and the respective RG Indices.

12 Concluding Remarks

Since their introduction in April 2018, the CDT series has progressively covered a growing number of interrelated areas, motivating over 47,000 reads and almost 1000 recommendations.

We thank our readers for reading, following and helping with the dissemination of the titles, looking forward to further extending the series through the incorporation of more titles on complementary subjects.

Acknowledgments.

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Costa's Didactic Texts – CDTs

CDTs intend to be a halfway point between a formal scientific article and a dissemination text in the sense that they: (i) explain and illustrate concepts in a more informal, graphical and accessible way than the typical scientific article; and (ii) provide more in-depth mathematical developments than a more traditional dissemination work.

It is hoped that CDTs can also incorporate new insights and analogies concerning the reported concepts and methods. We hope these characteristics will contribute to making CDTs interesting both to beginners as well as to more senior researchers.

Each CDT focuses on a limited set of interrelated concepts. Though attempting to be relatively self-contained, CDTs also aim at being relatively short. Links to related material are provided in order to provide some complementation of the covered subjects.

Observe that CDTs, which come with absolutely no warranty, are non distributable and for non-commercial use only.

Please check for new versions of CDTs, as they can be revised. Also, CDTs can and have been cited, e.g. by including the respective DOI. Please cite this CDT in case you use it, so that it may also be useful to other people. The complete set of CDTs can be found at: https://www.researchgate.net/project/Costas-Didactic-Texts-CDTs.