DOWNLOAD PDF COMPUTATIONAL HOMOLOGY (APPLIED MATHEMATICAL SCIENCES)

Chapter 1 : Computational topology - Wikipedia

I certainly recommend Computational Homology to mathematicians and applied scientists who wish to learn about the potential of algebraic topological methods. this book is the first comprehensive effort to describe the computational aspects of homology theory .

Michael Bronstein received the Ph. His main research interests are geometric methods in computer vision, pattern recognition, and computer graphics. He has served on program committees of major conferences in his field and was keynote speaker in numerous international symposia. Bronstein is also actively involved in technology transfer and consulting. His start-up track record includes Novafora as co-founder and VP of video technology and Invision as one of principle technologists. Since the acquisition of Invision by Intel in , Michael has also served as a Research Scientist at Intel, where he was one of the key algorithm developers for the RealSense 3D sensor. Illia Horenko is an associate professor in the faculty of informatics and the Institute of Computational Science of the University of Lugano. He received a Ph. His research interests are focused on the development and practical implementation of data analysis algorithms and time series analysis approaches. Published applications of the methods developed by I. Horenko has published over 40 papers in the professional literature. He was a co-organizer of several big scientific programs and is a frequent reviewer for international funding agencies and the top journals in his field. Deterministic Methods , Stochastic Methods Prof. He received a PhD in computer science from the University of Erlangen in and spent two years as a postdoctoral research fellow at Caltech in Pasadena and the CNR in Pisa, before joining Clausthal University of Technology as an assistant professor in His research interests are focussed on the mathematical foundations of geometry processing algorithms and their applications in computer graphics and related fields. In particular, he is working on generalized barycentric coordinates, subdivision of curves and surfaces, barycentric rational interpolation, and dynamic geometry processing. Rolf Krause is chair of advanced scientific computing and the director of the institute of computational science in the faculty of informatics. From to , he was professor at the University of Bonn. His research focuses on numerical simulation and mathematical modeling in scientific computing and computational sciences, in particular the development of theoretical well founded simulation methods, which show excellent performance also in real world applications. Igor Pivkin received his B. Specific areas include biophysics, cellular and molecular biomechanics, stochastic multiscale modeling, and coarse-grained molecular simulations. During those years, his research was focused on standard computational methodologies e. Here he did his PostDoc working in the field of enhanced sampling simulations used to study rare events in biosystems with a special focus on molecular binding processes. He is known for his many technical innovations in the field of atomistic simulations and for a wealth of interdisciplinary applications ranging from materials science to chemistry and biology. For his work he has been awarded the Prix Benoist and many others prizes and honorary degrees. He is the author of more than papers and his work is highly cited. From to she was a research staff member at the IBM T. She had also been a Faculty member in the department of computer science at the Athens University of Economics and Business. Her research interests include the design and analysis of discrete algorithms, computational geometry and its applications, software and implementation of geometric algorithms, data structures, and algorithmic aspects of VLSI computer-aided design. He conducts research in applied algorithms, computational science, and software tools for high-performance scientific computing. He is a recipient of an IBM faculty award and two leadership computing awards from the U. Department of Energy , High-Performance Computing , Software Atelier: Supercomputing and Simulations Prof. He is a member of the European Academy of Sciences and Arts, and has published more than peer-reviewed scientific papers on topics such as machine learning, mathematically optimal universal AI, artificial curiosity and creativity, artificial recurrent neural networks, adaptive robotics, complexity theory, digital physics, theory of beauty, and the fine arts. Between and he held an assistant professor position at the Faculty of Economics of the University of St. Since he is full professor of

Econometrics at USI. His research interests focus on econometrics and financial econometrics. He has published research papers on topics such as large panel factor models, nonparametric estimation, the Generalized Method of Moments in asset pricing, time series analysis, and credit risk. She is often invited to talk at international scientific conferences where she also organizes sessions on topics related to her research interests. Statistics Lecturers from Universita della Svizzera italiana Dr. His current research is on the emergence and evolution of social networks within online communities. Practice of Simulation and Data Sciences Dr. He worked as a post doctoral fellow at the department of Energy Resources Engineering of Stanford University on optimization of compositional reservoir flow in porous media. His research now focuses on inverse problems that emerge in reservoir modeling, seismic imaging and smart grids and it involves the development of associated high-performance algorithms and software tools.

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Chapter 2 : Applied and Computational Mathematics :: Science Publishing Group

Homology is a strong device utilized by mathematicians to review the houses of areas and maps which are insensitive to small perturbations. This publication makes use of a working laptop or computer to enhance a combinatorial computational method of the subject.

All students complete a core set of courses developing basic skills in modeling, computation, mathematics, and statistics. Students choose one of the eight option areas listed below for further training and specialization. Biological and Life Sciences focuses on basic techniques of mathematical modeling and computing that are employed in the life sciences. Discrete Mathematics and Algorithms gives students a broad background in mathematics and computation with special emphasis on discrete mathematics and its application to optimization and algorithm design. Engineering and Physical Sciences is an excellent choice for students with an interest in the physical world and classical areas of applied mathematics. Mathematical Economics provides a firm foundation in applied and computational mathematics as well as a basic grounding in economic theory. Operations Research provides a firm foundation in the mathematical tools of operations research, particularly optimization and stochastic modeling effective summer quarter , admission suspended until further notice. Scientific Computing and Numerical Algorithms focuses on the design, mathematical analysis, and efficient implementation of numerical algorithms for such problems. Social and Behavioral Sciences provides a foundation in commonly used statistical and computational techniques followed by flexibility in pursuing different sets of advanced courses. Data Science and Statistics focuses on building, using, and interpreting statistical models from scientific or engineering data. Completion of minimum requirements does not guarantee admission. Major Requirements 90 credits as follows: A minimum GPA of 2. Completion of one of the following options: Biological and Life Sciences Option. Discrete Mathematics and Algorithms Option. Remaining 15 credits from approved courses at the level or above from the four participating departments. Engineering and Physical Sciences Option. Option core 27 credits: Either 1 or 2 , below. As of summer quarter , admission to the Operations Research Option is suspended until further notice. Option core 30 credits: Scientific Computing and Numerical Algorithms Option. Social and Behavioral Sciences Option. Data Science and Statistics Option. See adviser for additional information on program options, for possible substitutions, and for approval of elective choices noted above. Continuation Policy All students must make satisfactory academic progress in the major. Failure to do so results in probation, which can lead to dismissal from the major. For the complete continuation policy, contact the departmental adviser or refer to the department website. The ACMS degree emphasizes the development of advanced skills in discrete and continuous mathematical modeling, computing and scientific computation, mathematical reasoning and analytic skills, and statistical reasoning and analytic skills. Students develop an expertise at an advanced level in an applications area. This set of skills provides the basis for careers in a wide array of quantitative disciplines including engineering; the physical, life, and social sciences; as well as business and management sciences. In addition, the ACMS program has developed partnerships with a number of departments on campus to facilitate the pursuit of double majors. Instructional and Research Facilities: The program has access to the combined instructional and research facilities of the four participating departments, as well as the Mathematics and Statistics library and the Math Study Center. See adviser for requirements. Research, Internships, and Service Learning: The program is provided with internship opportunities periodically, which are then passed on to students.

Chapter 3 : Institute of Computational Science - Master

Applied Mathematical Sciences Volume Editors S.S. Antman J.E. Marsden L. Sirovich Advisors J.K. Hale P. Holmes J. K.

Observe that the smooth curves have become chains of small squares. These squares represent the smallest geometric units of information presented in the image on the left-hand side. Given our goal of an automated method for image processing, it seems that these squares are a natural input for the computer. Hence we could enter the circles in Figure 1. More interesting images are, of course, more complicated. Consider the photo in Figure 1. This is a black-and-white photo that, if rendered on a computer screen, would be presented as a rectangular set of elements each one of which is called a picture element, or a pixel for short. This rendering captures the essential elements of a digital image: On the other hand, the Sea of Tranquillity is an analog rather than a digital object. Its physical presence is continuous in space and time. Furthermore, the visual intensity of the image that we would see if we were observing the moon directly also takes a continuum of values. Clearly, information is being lost 1. How many distinct bounded regions are in this complicated maze? On the left we have a simple image of two intersecting circles produced by a computer. Observe that the smooth curve is now a chain of squares that intersect either at a vertex or on a face. This is an important point and is the focus of considerable research in the image processing community. However, these problems lie outside the scope of this book and, with the exception of Section 8. The original is a mm black-and-white photo see the NASA web page http: How many are there? Thus we want to reduce this picture to a binary image that distinguishes between smooth and cratered surface areas. The simplest approach for reducing a gray-scale image to a binary image is image thresholding. One chooses a range of gray-scale values [T0 , T1]; all pixels whose values lie in [T0 , T1] are colored black while the others are left white. Of course, the resulting binary image depends greatly on the values of T0 and T1 that are chosen. Again, the question of the optimal choice of [T0 , T1] and the development of more sophisticated reduction techniques are serious problems that are not dealt with in this book. Having acknowledged the simplistic approach we are adopting here, consider Figure 1. These binary images were obtained from Figure 1. Recall that in a gray-scale image each pixel has a value between 0 and , where 0 is black and is white. The craters are darker in color which corresponds to a lower gray-scale value. Pixels in theses ranges are taken to represent the smooth surface: In other words, the black 1. Counting the number of holes white regions bounded by black pixels in the binary pictures provides an approximation of the number of craters in the picture. Observe that we are back to the problem motivated by Figures 1. The examples presented so far, namely Figures 1. The full mathematical machinery of homology is not necessary to analyze such simple images in the plane, and we do not recommend the material in this book for a reader whose only interest is in counting craters on the moon. This latter task requires no knowledge of homology. On the other hand, many physical problems are higher-dimensional, where our visual intuition fails and topological reasoning becomes crucial. Consider a binary alloy consisting of iron Fe and chromium Cr created by heating the metals to a high temperature. However, upon cooling, the iron and chromium atoms separate, leading to a two-phase microstructure; that is, the material divides into regions that consist primarily of iron atoms or chromium atoms, but not both. These regions, which we will denote by F t for iron and C t for chromium, are obviously three-dimensional structures, can be extremely 10 1 Preview complicated, and furthermore, change their form with time t. Current technology allows for accurate three-dimensional measurements to be performed on the atomic level essentially the material is serially sectioned and then examined with an atomic probe; see [53] for details. Thus these regions can be experimentally determined. On the theoretical side there are mathematical models meant to describe this process of decomposition. For example, Figure 1. Returning to the issue of modelling alloys, the assumption is that positive values of u indicate higher density of one element and that negative values of u indicate higher density of the other element. We now wish to compare F t0 against R1 t0 and C t0 against R2 t0. Instead we ask if they are similar in the sense of their topology. This is a standard procedure in computer graphics as it produces an object that is much more pleasant to view. There can be tunnels that pass through the regions and even hollow cavities. Of course, these comparisons ignore the question of cavities. These types of comparisons are performed in [39]. There are probably two reasons for this. First, this vocabulary is not common knowledge in the metallurgy community. Second, and more importantly, because the regions are three-dimensional, computational tricks can be employed to circumvent the need to explicitly compute the homology groups. The intention of the last sentence by no means is to suggest that the reader who is interested in these kinds of problems can avoid learning homology theory. This dichotomy between the algebraic theory and the computational methods will be made clear in this book. Thus in Chapter 3 we provide a purely algebraic algorithm for computing homology. This guarantees that homology groups are always computable. Thus in Chapter 4 we introduce reduction algorithms that are combinatorial in nature and reasonably fast. In the next example, which is essentially four-dimensional, the tricks employed by [39] no longer work, and even on the level of language we can begin to appreciate the advantage of an abstract algebraic approach to the topic. Combining these two-dimensional images results in a three-dimensional image made up of three-dimensional cubes or voxels. As in the case of the lunar photo, a gray scale is assigned to each voxel. Assume that by using appropriate thresholding techniques we can identify those voxels that correspond to heart tissue. However, medical technology allows us to go further. Multiple images can be obtained within the time span of a single heartbeat. Thus the full data set results in a four-dimensional objectâ€"three space dimensions and one time dimensionâ€"where the individual data elements are four-dimensional cubes or tetrapus. At this stage standard English begins to fail. As a simple example, consider a chamber of the heart at an instant of time when the valves are closed. In this case, the chamber is a cavity in a three-dimensional object. However, if we include time, then the valve will open and close so the threedimensional cavity does not lead to a four-dimensional cavity. Which of the 1. By the end of Chapter 2 the reader will know the answer. We now turn to problems where it is important to have algorithms for studying nonlinear functions. As motivation we turn to a simple model for population dynamics. Let yn represent a population at time n. This issue can be avoided by assuming that the rate of growth is a decreasing function of the population. Notice that the new variable xn represents the scaled population level at time n. A natural question is: Given an initial population level x0 , what are the future levels of the population? Notice that producing the sequence of population levels x0 , x1 , x2 ,. Clearly, one can write a simple program that performs such an operation. However, before doing so we wish to make two observations. So if we begin with the restricted initial conditions, then our population always remains nonnegative. Do initial conditions exist that lead to periodic orbits of a given period? In this case we would say that we have found a periodic orbit with minimal period k. What is the set of all k for which there exists a periodic orbit with minimal period k? How many such orbits are there? Are there many orbits that, like that of Figure 1. Are there any simple rules that such orbits must satisfy? Moreover, in many applications one is forced to deal with a map f: For this particular map, answers to even the third and fourth questions are reasonably well understood [73]. However, given a particular function f: With this in mind, let us return to the numerically computed orbit of Figure 1.

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Chapter 4 : Applied and Computational Mathematical Sciences

THREE EXAMPLES OF APPLIED & COMPUTATIONAL HOMOLOGY Robert Ghrist 1 Algebraic Topology as Applied Mathe-matics? Mathematics is limitless in its dual capacity for.

Major algorithms by subject area[edit] Algorithmic 3-manifold theory[edit] A large family of algorithms concerning 3-manifolds revolve around normal surface theory, which is a phrase that encompasses several techniques to turn problems in 3-manifold theory into integer linear programming problems. This is an algorithm that takes as input a triangulated 3-manifold and determines whether or not the manifold is homeomorphic to the 3-sphere. It has exponential run-time in the number of tetrahedral simplexes in the initial 3-manifold, and also an exponential memory profile. Moreover, it is implemented in the software package Regina. He uses instanton gauge theory, the geometrization theorem of 3-manifolds, and subsequent work of Greg Kuperberg [5] on the complexity of knottedness detection. The connect-sum decomposition of 3-manifolds is also implemented in Regina , has exponential run-time and is based on a similar algorithm to the 3-sphere recognition algorithm. Determining that the Seifert-Weber 3-manifold contains no incompressible surface has been algorithmically implemented by Burton, Rubinstein and Tillmann [6] and based on normal surface theory. The Manning algorithm is an algorithm to find hyperbolic structures on 3-manifolds whose fundamental group have a solution to the word problem. Neither has the compression-body decomposition. There are some very popular and successful heuristics, such as SnapPea which has much success computing approximate hyperbolic structures on triangulated 3-manifolds. It is known that the full classification of 3-manifolds can be done algorithmically. This algorithm has a roughly linear run-time in the number of crossings in the diagram, and low memory profile. The algorithm is similar to the Wirthinger algorithm for constructing presentations of the fundamental group of link complements given by planar diagrams. Similarly, SnapPea can convert surgery presentations of 3-manifolds into triangulations of the presented 3-manifold. Costantino have a procedure to construct a triangulated 4-manifold from a triangulated 3-manifold. Similarly, it can be used to construct surgery presentations of triangulated 3-manifolds, although the procedure is not explicitly written as an algorithm in principle it should have polynomial run-time in the number of tetrahedra of the given 3-manifold triangulation. Schleimer has an algorithm which produces a triangulated 3-manifold, given input a word in Dehn twist generators for the mapping class group of a surface. The 3-manifold is the one that uses the word as the attaching map for a Heegaard splitting of the 3-manifold. The algorithm is based on the concept of a layered triangulation. Algorithmic knot theory[edit] Determining whether or not a knot is trivial is known to be in the complexity class NP [10] The problem of determining the genus of a knot is known to have complexity class PSPACE. There are polynomial-time algorithms for the computation of the Alexander polynomial of a knot.

Chapter 5 : Computational Homology - Tomasz Kaczynski, Konstantin Mischaikow, Marian Mrozek - Google

The material is aimed at a broad audience of engineers, computer scientists, nonlinear scientists, and applied mathematicians. Mathematical prerequisites have been kept to a minimum and there are numerous examples and exercises throughout the text.

Chapter 6 : Computational Homology

1 1 1 1 NAW 5/9 nr. 2 June Three examples of applied & computational homology Robert Ghrist Robert Ghrist Department of Mathematics and Coordinated Science Laboratory.

Chapter 7 : Computational Homology by Tomasz Kaczynski

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Homology theory enters applied mathematics in an increasing number of ways. The reader of "Computational Homology" will find ample evidence of the relevance of homology to problems in vision and segmentation, pattern formation and classification, and dynamical systems.

Chapter 8 : Persistent Homology Analysis of Biomolecular Data

Homology is a powerful tool used by mathematicians to study the properties of spaces and maps that are insensitive to small perturbations. This book uses a computer to develop a combinatorial computational approach to the subject. The core of the book deals with homology theory and its computation.

Chapter 9 : Computational Homology (Applied Mathematical Sciences) - PDF Free Download

This chapter justifies a "computational level" of biological analysis and present the concepts of "computational homology" and "computype," which pave the way to their thesis that FL can be homologized with an extremely large natural class of "computational systems," most probably extending to the whole family of vertebrates, no matter the behaviors these systems underlie and.