Ashraf M.T. Elewa *Editor*

Computational Paleontology

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Foreword

Computers and quantitative methods are fundamental tools in all branches of modern science, and paleontology is no exception. It has not always been this way, however. Quantitative approaches were of course always used by paleontologists, but the mainstream literature used to focus on qualitative description. In general, paleontology was surprisingly slow in adopting quantitative methods, compared with geology and particularly biology. One reason could be the idea that the fossil record is too incomplete for statistical treatment. What is the point of using sophisticated methods on such poor data? This is a misunderstanding – in fact the opposite is the case. It is precisely when the data are incomplete that we need the machinery of statistics to assess the effects of sampling. On the subject of mathematical modelling, a common objection is that the complexities of biological systems cannot be captured in a simple model. Again I would argue otherwise, that exactly when the system is complex beyond the capabilities of the human brain, a reduced model can lead to fundamental understanding by virtue of its very simplicity. After all, the purpose of modelling in paleontology is insight, not prediction.

A spectacular, early application of computers in paleontology was Raup's modelling of shell coiling. Another pioneer was Richard Reyment, who contributes to this volume. Now, computers are used almost everywhere in the paleontological work flow, from field work, data collection and visualization (Mallison; Poza-Rey; Stoinski; this volume) to morphometrics (Reyment) and data management (Skjerpen and Dolven). Quantitative methods are also fundamental in studies of paleoecology, development and evolution (Brusatte; Zachos and Sprinkle; Weaver; Petrakis). Paleontology as a science has improved as a consequence of this development. Quantitative approaches do not always give more "correct" answers, but they do make the arguments clearer and the results easier to falsify. Also, modern methods of data analysis and visualization have the power to suggest new research questions that would not have appeared otherwise.

There is something intriguing about the combination of modern technology and the vastness of geological time. The use of laser scanners, CT machines or DNA sequencing on fossils rarely fails to interest the media. This fascination was used to full effect in the blockbuster movie Jurassic Park (1993), where molecular biology and computer science interfinger with the horrors of the Mesozoic. This movie was also a technological breakthrough concerning the use of 3D computer graphics for visualizing ancient life forms. Such technology has since been used in countless movies and TV documentaries, contributing greatly to the present interest in paleontology among the general public.

Finally a piece of informal scientometrics: The ratio between hits for "computational paleontology" and "paleontology" on Google is presently 0.0036%. We therefore have some way to go compared with physics or biology, where the similar ratios are 1.3 and 2.0%. Slightly more alarming is the ratio for the "soft" science of archaeology, at 0.0049%. Hopefully, this book will contribute to us beating the archaeologists!

Oslo, Norway Oyvind Hammer

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Chapter 1
Computational Paleontology

Ashraf M.T. Elewa

Computational paleontology is simply a term applied to using computers and its facilities in the field of paleontology. However, we should be exactly specific in describing the term through explaining the main themes of this motivating and attractive scientific field.

Although the idea of using computer for solving paleontological problems is not new, but Oyvind Hammer, the famous Norwegian paleontologist and mathematician, introduced the term "computational paleontology" to the public through his computational paleontology webpage (1996). He described the term as the use of mathematical models, simulation, computer graphics and computers in paleontology. I know Oyvind since several years and I believe he is one of the pioneers in this field. He, together with David Harper and Paul Ryan, developed their Paleontological Statistics Software Package for Education and Data Analysis (PAST) in the year 2001 (see Hammer et al. 2001). Oyvind considered PAST as a follow-up to PALSTAT extensive package of Ryan et al. (1995).

It is worth mentioning that some paleontologists use the phrase "computer-assisted paleontology", some others prefer to use the idiom "computer-aided paleontology", still the expression "computational paleontology" sounds more relevant.

One of the earliest books to discuss the subject is that titled "Multidimensional Paleobiology" by Reyment (1991). Eight years later, Reyment and Savazzi (1999) introduced computational examples on the frequencies of fossils species as one of eight kinds of data encountered by geologists. They devoted chapter two of their book to describe the use of graphic software available on a CD accompanying the book.

Uhen (2000) mentioned the following criticism to the book titled "Numerical Palaeobiology: Computer-Based Modelling and Analysis of Fossils and Their Distributions", by Harper (1999): As for most people, much of what paleontologists do with computers is mundane and rather uninteresting. We type manuscripts,

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we create figures, we send and receive e-mail. Dispensing with these sorts of applications, Harper presents an eclectic collection of papers on topics covering computer-based analyses of fossils, from individual specimens to the entire fossil biota. I was generally pleased with the individual chapters but was somewhat disappointed with the lack of discussion of the status of “numerical paleobiology” in general.

In a paper titled “Graphics in computational paleontology”, which was published in the Computer Graphics and applications, IEEE, Figgins (2001) stated that we should search for the buried keys in the past to unlocking our understanding of the form. He added that we may still use tools such as picks and shovels to uncover them, but today paleontologists are also using computers and graphics to dig into the past.

David Lewin (2002) tried, by using sophisticated computer programs, to answer questions related to how fast the tyrannosaur can run and whether the triceratops sprawl or stand straight. His interest is to use combined techniques from computer-aided design, rapid prototyping, and biomechanics for developing more accurate theories of dinosaurs’ posture and movements.

In August, 2005, Christoph P. Zollikofer and Marcia Ponce de Leon published a book titled “Virtual Reconstruction: A Primer in Computer-Assisted Paleontology and Biomedicine”. They argued that virtual reconstruction serves as an introduction to the principles of three-dimensional visualization techniques as they relate to fossil reconstruction and reverse engineering.

One of the most effective ways to facilitate wide spreading of paleontology is electronic publications. Elewa (2007) discussed the efficiency of the electronic journal “Palaeontologia Electronica” in a paper titled “A Powerful Electronic Journal in the New Millennium”.

Tammy Dunlavey, of the Department of Geology in the UB College of Arts and Sciences, and her colleagues tried to develop a computational method to morph fossils back to their original shapes by calculating and excising the deformation. Their goal was to develop computer programs that can reliably solve the deformation problems related to burial of fossils deep in layers of rocks for thousands or millions of years [see University At Buffalo (2004)].

There are several software packages that are used for mathematical calculations and graphical representations concerning paleontological data (e.g., PAST, IMP, TPS, MORPHEUS et al, MORPHOMATICA, ... etc.), however Tapanila (2007) produced a new software, which is a new Excel-based spreadsheet application of the Sepkoski Compendium designed for educational use in paleontology and historical geology courses.

In summary, it could be declared that almost multivariate geostatistics are not commonly observed as fascinating subject matter (see Reyment and Savazzi 1999), yet our area under contemplation “computational paleontology” is an exception.

Consequently, it is imperative to point out the main discussed topics in this volume in the following:

1. What is computational paleontology?
2. Computational taxonomy and systematics

3. Paleontological information systems (paleoinformatics)
4. Computational functional morphology
5. Computation of growth and form
6. Mathematics and statistics for paleontology
7. 2D and 3D graphical representations of paleontological data
8. Computational genetics and heritage
9. Future insights

Looking to the above mentioned topics, Elewa has published several papers on topics 2, 5 and 6 (e.g., Elewa and Ishizaki 1994; Elewa et al. 1995, 1999, 2001; Elewa 1997, 1998, 1999, 2002, 2003, 2004; Reyment and Elewa 2002; Elewa and Morsi 2004). Moreover, Elewa edited two books on the topic "moprhometrics" (2004, 2010), which is considered as one of the topics related to mathematical and graphical representations of forms; including fossils.

In an international Senckenberg conference and workshop titled "Paleontology in the 21st Century", Norman MacLeod and Robert Guralnick (1997, 2000) stated that paleoinformatics is that area of paleontology concerned the management of information, including the preservation of systematic information and expertise. They argued that because paleontology is such an information-rich and integrative field, the management of its data has always been problematic. I would add that another serious problem is located in the isolation between paleontologists and taxonomists in which each team is working without knowledge of the work of the other team. Therefore, it is compulsory to unify the nomenclatures of both teams under same identification, and then we can make accurate databases of taxonomic works, which will be applicable to the two teams.

In an interesting article related to computational functional morphology, Susan Rigby and Gavin Tabor (2006) used computational fluid dynamics in reconstructing the hydrodynamic properties of graptolites. They suggest that major improvements in our understanding of graptolite functional morphology will result from further use of this novel technique.

The uppermost aim of editing this book is to explain how computation could be competent in fetching fossils to life and the past to present. Computers for paleontologists save time and costs, interpret mysterious events precisely and accurately, visualize the ancient life definitely and undeniably.

Proudly, I could select an outstanding team of experts to write professionally on computational paleontology. No doubt, without their contributions this book could not be completed. I also would like to pass my great appreciation and respect to Oyvind Hammer for writing the forward to this book.

No doubt, computational paleontology techniques are frequently used by many students, researchers, and professionals. As well, this book introduces up to date information and useful ideas on the subject. I hope readers enjoy reading the chapters of this book in a manner promising to open a new gate to modern paleontology.

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