Computational Biology

Bir Bhanu
Prue Talbot *Editors*

Video Bioinformatics

From Live Imaging to Knowledge

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Computational Biology

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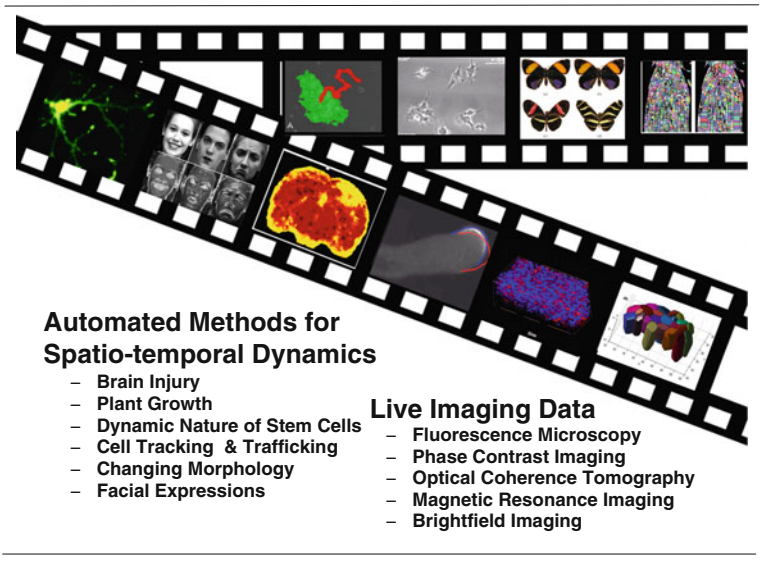

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Preface

The recent advances in high-throughput technologies for functional genomics and proteomics have revolutionized our understanding of living processes. However, these technologies, for the most part, are limited to a *snapshot analysis* of biological processes that are by nature *continuous and dynamic*. Modern visual microscopy enables video imaging of cellular and molecular dynamic events and provides unprecedented opportunities to understand how spatiotemporal dynamic processes work in a cellular and multicellular system. The application of these technologies is becoming a mainstay of the biological sciences worldwide. To gain a more mechanistic and systematic understanding of biological processes, we need to elucidate cellular and molecular dynamic processes and events.

Video Bioinformatics *as defined by the first author* (*BB*) *is concerned with the automated processing, analysis, understanding, data mining, visualization, query-based retrieval/storage of biological spatiotemporal events/data and knowledge extracted from microscopic videos. It integrates expertise from the life sciences, computer science and engineering to enable breakthrough capabilities in understanding continuous biological processes.* The video bioinformatics information related to spatiotemporal dynamics of specific molecules/cells and their interactions in conjunction with genome sequences are essential to understand how genomes create cells, how cells constitute organisms, and how errant cells cause disease.

Currently, new imaging instrumentation and devices perform *live video imaging* to image molecules and subcellular structures in living cells and collect biological videos for on-line/off-line processing. We can now see and study the complex molecular machinery responsible for the formation of new cells. Multiple imaging modalities can provide 2D to 5D (3D space, time, frequency/wavelength) data since we can image 2D/3D objects for seconds to months and at many different wavelengths. However, data processing and analysis (informatics) techniques for handling biological images/videos have lagged significantly and they are at their infancy. There are several reasons for this, such as the complexity of biological videos which are more challenging than the structured medical data, and the lack of

interdisciplinary research at the intersection of life sciences and engineering and computer science.

We already are at a point where researchers are overwhelmed by myriads of high-quality videos without proper tools for their organization, analysis, and interpretation. This is the main reason why video data are currently underutilized. We believe that the next major advance in imaging of biological samples will come from advances in the automated analysis of multi-dimensional images. Having tools that enable processes to be studied rapidly and conveniently over time will, like Hooke's light microscope and Ruska's electron microscope, open up a new world of analysis to biologists, scientists, and engineers.

This interdisciplinary book on *Video Bioinformatics* presents computational techniques for the solution of biological problems of significant current interest such as 2D/3D live imaging, mild-traumatic brain injury, human embryonic stem cells, growth of pollen tubes, cell tracking, cell trafficking, etc. The analytical approaches presented here will enable the study of biological processes in 5D in large video sequences and databases. These computational techniques will provide greater sensitivity, objectivity, and repeatability of biological experiments. This will make it possible for massive volumes of video data to be analyzed efficiently, and many of the fundamental questions in life sciences and informatics be answered. The book provides examples of these challenges for video understanding of cell dynamics by developing innovative techniques. Multiple imaging modalities at varying spatial and temporal resolutions are used in conjunction with computational methods for video mining and knowledge discovery.

The book deals with many of the aspects of the video bioinformatics as defined above. Most of the chapters that follow represent the work that was completed as part of an NSF-funded IGERT program in Video Bioinformatics at the University of California in Riverside. Several of the chapters deal with work that keynote speakers presented at retreats sponsored by this program (Chaps. 14 and 16). Most other chapters are work done by IGERT Ph.D. fellows who were selected to participate in this program. The program emphasizes an interdisciplinary approach to data analysis with graduate students from engineering and life sciences being paired to work together as teams. These resulting chapters would likely never have been produced without cooperation between these two distinct disciplines and demonstrate the power of this type in interdisciplinary cooperation.

We appreciate the suggestions, support feedback and encouragement received from the IGERT faculty, IGERT fellows and NSF IGERT Program Directors Richard Tankersley, M.K. Ramasubramanian, Vikram Jaswal, Holly K. Given, and Carol Stoel. Authors would like to thank Dean Reza Abbaschian, Dean Joe Childers, Dallas Rabenstein, David Eastman, Victor Rodgers, Zhenbiao Yang, Vassilis Tsotras, Dimitri Morikis, Aaron Seitz, Jiayu Liao, David Carter, Jerry Schultz, Lisa Kohne, Bill Bingham, Mitch Boretz, Jhon Gonzalez, Michael Caputo, Michael Dang and Benjamin Davis for their support and help with the IGERT program. Authors would also like to thank Atena Zahedi for the sketch shown on the inside title page. Further, the authors would like to thank Simon Rees and Wayne Wheeler of Springer and Priyadarshini Senthilkumar (Scientific Publishing

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Riverside, CA, USA Bir Bhanu
June 2015 Prue Talbot

List of Video Links with QR Codes

Software for Using QR Codes:

In order to scan a QR Code you must install a QR Code reader app on your smartphone. You can download an app on Google Play (Android Market), Blackberry AppWorld, App Store (iOS/iPhone), or Windows Phone Marketplace.

- Most QR scanning apps are free. Any app that can read barcodes should be able to process QR codes.
- Recommended for Android: Google Goggles Version 1.9.4
- Recommended for iOS: Quick Scan—QR Code Reader Version 1.1.5

Hyperlinks and QR Codes for each Video Referenced in the Book

IGERT on Video Bioinformatics YouTube Channel:
https://www.youtube.com/channel/UCX9tYZRm-mGwhg6866FWizA

Chapter 6:
Video 1: https://www.youtube.com/watch?v=3ylu3oHZEC4

Video 2: https://www.youtube.com/watch?v=sfNhuK9JSxA

Chapter 8:
Video 1: https://www.youtube.com/watch?v=dQTkldB8lNk

Video 2: https://www.youtube.com/watch?v=NgJZ49xgev8

Video 3: https://www.youtube.com/watch?v=plb_CInFoEY

Video 4: https://www.youtube.com/watch?v=tHJ5JDcpkWY

Chapter 9:
Video 1: https://www.youtube.com/watch?v=wN1F_K_2vsg

Video 2: https://www.youtube.com/watch?v=INrVYlemvCY

Video 3: https://www.youtube.com/watch?v=xUcU3HpiMwI

Video 4: https://www.youtube.com/watch?v=RAiqZtK80Dw

Video 5: https://www.youtube.com/watch?v=hYayvIvuzOM

Video 6: https://www.youtube.com/watch?v=KLaFIhkovPI

Video 7: https://www.youtube.com/watch?v=Orw_lUs8KFI

Video 8: https://www.youtube.com/watch?v=M-asAiwiLnM

Video 9: https://www.youtube.com/watch?v=OHD0j74qbk0

Video 10: https://www.youtube.com/watch?v=aZlbfqfDDyg

Video 11: https://www.youtube.com/watch?v=OTBt1WBqqGw

Chapter 11:
Video 1: https://www.youtube.com/watch?v=l-Sb2iqzw1Y

Chapter 12:
Video 1: https://www.youtube.com/watch?v=jvdL7L4nQIs

Chapter 15:
Video 1: https://www.youtube.com/watch?v=pxg14SdvNbE

Video 2: https://www.youtube.com/watch?v=NnPHrGxJ7j0

Chapter 18:
Video 1: https://www.youtube.com/watch?v=6KZc6e_EuCg

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