A composite visualization method for electrophysiology-morphous merging of human heart

Fei Yang, Lei Zhang, Weigang Lu, Yue Zhang, Wangmeng Zuo, Kuanquan Wang, and Henggui Zhang

Abstract—Background: Electrophysiological behavior is of great importance for analyzing the cardiac functional mechanism under cardiac physiological and pathological condition. Due to the complexity of cardiac structure and biophysiological function, visualization of a cardiac electrophysiological model compositively is still a challenge. The lack of either modality of the whole organ structure or cardiac electrophysiological behaviors makes analysis of the intricate mechanisms of cardiac dynamic function a difficult task. This study aims at exploring 3D conduction of stimulus and electrical excitation reactivity on the level of organ with the authentic fine cardiac anatomy structure.
Methods: In this paper, a cardiac electrical excitation propagation model is established based on the human cardiac cross-sectional data to explore detailed cardiac electrical activities. A novel biophysical merging visualization method is then presented for biophysical integration of cardiac anatomy and electrophysiological properties in the form of the merging optical model, which provides the corresponding position, spatial relationship and the whole process in 3D space with the context of anatomical structure for representing the biophysical detailed electrophysiological activity.
Results: The visualization result present the action potential propagation of the left ventricle within the excitation cycle with the authentic fine cardiac organ anatomy. In the visualized images, all vital organs are identified and distinguished without ambiguity. The three dimensional spatial position, relation and the process of cardiac excitation conduction and re-entry propagation in the anatomical structure during the phase of depolarization and repolarization is also shown in the result images, which exhibits the performance of a more detailed biophysical understanding of the electrophysiological kinetics of human heart in vivo.
Conclusions: Results suggest that the proposed merging optical model can merge cardiac electrophysiological activity with the anatomy structure. By specifying the respective opacity for the cardiac anatomy structure and the electrophysiological model in the merging attenuation function, the visualized images can provide an in-depth insight into the biophysical detailed cardiac functioning phenomena and the corresponding electrophysiological behavior mechanism, which is helpful for further speculating cardiac physiological and pathological responses and is fundamental to the cardiac research and clinical diagnoses.
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Keywords: Computational cardiology, Morphous Biophysical merging, Cardiac biophysiological function, Merging attenuation model

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1 BACKGROUND

The cardiac disease, e.g., atrioventricular block, ventricular fibrillation and cardiomyopathy, is one of the most common causes of mortality in the world. It has been proven that cardiac functional abnormity may produce the serious problem of heart disability and are generally life-threatening [1]. Although there are considerable progresses have been achieved on conventional open-heart research and acquirement of experimental and clinical data, the cardiac mechanisms aren't well understood. Increasing mo-

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mentum is tending to study the cardiac biophysiological function noninvasively [2], [3], [4]. Serpooshan et al. [5] analyzed the structure and function of the failing heart to enhance cardiac healing after injury. Zhang et al. [6] visualized cardiac microvessels embolization in 3D space with X-ray phase contrast images. This method was beneficial to diagnoses and predicting and judging the prognosis in myocardial infarction (MI). Based on the surface shape space Taimouri and Hua [7] et al. defined two novel shape descriptors by the geodesic distance connecting two points in the two cardiac medial surfaces, which quantitatively analyzed the similarity and disparity of the 3D heart motions between the healthy and myopathic subjects and accurately detected myopathic regions on the left ventricle. Spicher et al. [8] proposed a new cardiac triggering method to estimate the cardiac cycle phase in real-time from videos captured with an in-bore camera. However, the function mechanisms and the underlying genesis of human heart still remain unclear.

Electrophysiological behavior is of great importance for analyzing the functional mechanism under cardiac physiological and pathological condition. Noble [9] first applied the cell mathematical model-HH model to the purkinje fibre and pace-maker cells and started the research on

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   Encyclopedia of Software Engineering Three-Volume Set (Print) Phillip A. Laplante,2010-11-22 Software engineering requires specialized knowledge of a broad spectrum of topics including the construction of software and the platforms applications and environments in which the software operates as well as an understanding of the people who build and use the software Offering an authoritative perspective the two volumes of the Encyclopedia of Software Engineering cover the entire multidisciplinary scope of this important field More than 200 expert contributors and reviewers from industry and academia across 21 countries provide easy to read entries that cover software requirements design construction testing maintenance configuration management quality control and software engineering management tools and methods Editor Phillip A Laplante uses the most universally recognized definition of the areas of relevance to software engineering the Software Engineering Body of Knowledge SWEBOK as a template for organizing the material Also available in an electronic format this encyclopedia supplies software engineering students IT professionals researchers managers and scholars with unrivaled coverage of the topics that encompass this ever changing field Also Available Online This Taylor E mail e reference taylorandfrancis com International Tel 44 0 20 7017 6062 E mail online sales tandf co uk   **Computer Science Handbook** Allen B. Tucker,2004-06-28 When you think about how far and fast computer science has progressed in recent years it s not hard to conclude that a seven year old handbook may fall a little short of the kind of reference today s computer scientists software engineers and IT professionals need With a broadened scope more emphasis on applied computing and more than 70 chap   Advances in Computer Communication and Computational Sciences Sanjiv K. Bhatia,Shailesh Tiwari,Krishn K. Mishra,Munesh C. Trivedi,2018-08-22 The book includes the insights that reflect Advances in Computer and Computational Sciences from upcoming researchers and leading academicians across the globe It contains the high quality peer reviewed papers of International Conference on Computer Communication and Computational Sciences IC4S 2017 held during 11 12 October 2017 in Thailand These papers are arranged in the form of chapters The content of this book is divided into two volumes that cover variety of topics such as intelligent hardware and software design advanced communications intelligent computing techniques intelligent image processing and web and informatics This book helps the perspective readers from computer industry and academia to derive the advances of next generation computer and communication technology and shape them into real life applications   **AI*IA 2007: Artificial Intelligence and Human-Oriented Computing** Associazione italiana per l'intelligenza artificiale. Congress,Roberto Basili,Maria Teresa Pazienza,2007-08-28 Annotation This book constitutes the refereed proceedings of the 10th Congress of the Italian Association for Artificial Intelligence AI IA 2007 held in Rome Italy in September 2007 The 42 revised full papers presented together with 14 revised poster papers and 3 invited talks were carefully reviewed and selected from 80 submissions The papers are organized in topical sections on knowledge representation and reasoning multiagent systems distributed AIai knowledge engineering ontologies and the

semantic Web machine learning natural language processing information retrieval and extraction planning and scheduling AI and applications Three special tracks depicting progresses in significant application fields that represent increasingly relevant topics contain 18 additional papers on AI and robotics AI and expressive media and intelligent access to multimedia information **Digital Advances in Medicine, E-Health, and Communication Technologies** Rodrigues, Joel J.P.C.,2013-01-31 Digital Advances in Medicine E Health and Communication Technologies explores the developments and trends in medical informatics and its approaches toward telemedicine and e health applications This comprehensive collection of research brings together academia and industry by highlighting recent advances in electronic health medical communications and applications for e health and medicine **Computer Vision** Richard Szeliski,2022-01-03 Computer Vision Algorithms and Applications explores the variety of techniques used to analyze and interpret images It also describes challenging real world applications where vision is being successfully used both in specialized applications such as image search and autonomous navigation as well as for fun consumer level tasks that students can apply to their own personal photos and videos More than just a source of recipes this exceptionally authoritative and comprehensive textbook reference takes a scientific approach to the formulation of computer vision problems These problems are then analyzed using the latest classical and deep learning models and solved using rigorous engineering principles Topics and features Structured to support active curricula and project oriented courses with tips in the Introduction for using the book in a variety of customized courses Incorporates totally new material on deep learning and applications such as mobile computational photography autonomous navigation and augmented reality Presents exercises at the end of each chapter with a heavy emphasis on testing algorithms and containing numerous suggestions for small mid term projects Includes 1 500 new citations and 200 new figures that cover the tremendous developments from the last decade Provides additional material and more detailed mathematical topics in the Appendices which cover linear algebra numerical techniques estimation theory datasets and software Suitable for an upper level undergraduate or graduate level course in computer science or engineering this textbook focuses on basic techniques that work under real world conditions and encourages students to push their creative boundaries Its design and exposition also make it eminently suitable as a unique reference to the fundamental techniques and current research literature in computer vision **Testing Object-oriented Systems** Robert Binder,2000 More than ever mission critical and business critical applications depend on object oriented OO software Testing techniques tailored to the unique challenges of OO technology are necessary to achieve high reliability and quality Testing Object Oriented Systems Models Patterns and Tools is an authoritative guide to designing and automating test suites for OO applications This comprehensive book explains why testing must be model based and provides in depth coverage of techniques to develop testable models from state machines combinational logic and the Unified Modeling Language UML It introduces the test design pattern and presents 37 patterns that explain how to design responsibility based test suites how to tailor integration and regression testing for OO

code how to test reusable components and frameworks and how to develop highly effective test suites from use cases Effective testing must be automated and must leverage object technology The author describes how to design and code specification based assertions to offset testability losses due to inheritance and polymorphism Fifteen micro patterns present oracle strategies practical solutions for one of the hardest problems in test design Seventeen design patterns explain how to automate your test suites with a coherent OO test harness framework The author provides thorough coverage of testing issues such as The bug hazards of OO programming and differences from testing procedural code How to design responsibility based tests for classes clusters and subsystems using class invariants interface data flow models hierarchic state machines class associations and scenario analysis How to support reuse by effective testing of abstract classes generic classes components and frameworks How to choose an integration strategy that supports iterative and incremental development How to achieve comprehensive system testing with testable use cases How to choose a regression test approach How to develop expected test results and evaluate the post test state of an object How to automate testing with assertions OO test drivers stubs and test frameworks Real world experience world class best practices and the latest research in object oriented testing are included Practical examples illustrate test design and test automation for Ada 95 C Eiffel Java Objective C and Smalltalk The UML is used throughout but the test design patterns apply to systems developed with any OO language or methodology 0201809389B04062001 *Ewa Orłowska on Relational Methods in Logic and Computer Science* Joanna Golińska-Pilarek,Michał Zawidzki,2018-12-08 This book is a tribute to Professor Ewa Or owska a Polish logician who was celebrating the 60th year of her scientific career in 2017 It offers a collection of contributed papers by different authors and covers the most important areas of her research Prof Or owska made significant contributions to many fields of logic such as proof theory algebraic methods in logic and knowledge representation and her work has been published in 3 monographs and over 100 articles in internationally acclaimed journals and conference proceedings The book also includes Prof Or owska s autobiography bibliography and a trialogue between her and the editors of the volume as well as contributors biographical notes and is suitable for scholars and students of logic who are interested in understanding more about Prof Or owska s work *Natural Computing for Simulation and Knowledge Discovery* Nunes de Castro, Leandro,2013-07-31 Nature has long provided the inspiration for a variety of scientific discoveries in engineering biomedicine and computing though only recently have these elements of nature been used directly in computational systems Natural Computing for Simulation and Knowledge Discovery investigates the latest developments in nature influenced technologies Within its pages readers will find an in depth analysis of such advances as cryptographic solutions based on cell division the creation and manipulation of biological computers and particle swarm optimization techniques Scientists practitioners and students in fields such as computing mathematics and molecular science will make use of this essential reference to explore current trends in natural computation and advance nature inspired technologies to the next generation **Supporting Learning Flow Through Integrative**

Technologies Tsukasa Hirashima,Ulrich Hoppe,Shelley Shwu-Ching Young,2007 Contains a range of issues related to using information technology for learning This book indicates a move from local support of specific learning activities towards supporting learning and teaching processes in a broader context beyond single tools and individuals users considering user learner groups on different levels of granularity **Large-Scale Distributed Computing and Applications: Models and Trends** Cristea, Valentin,Dobre, Ciprian,Stratan, Corina,Pop, Florin,Costan, Alexandru,2010-05-31 Many applications follow the distributed computing paradigm in which parts of the application are executed on different network interconnected computers The extension of these applications in terms of number of users or size has led to an unprecedented increase in the scale of the infrastructure that supports them Large Scale Distributed Computing and Applications Models and Trends offers a coherent and realistic image of today s research results in large scale distributed systems explains state of the art technological solutions for the main issues regarding large scale distributed systems and presents the benefits of using large scale distributed systems and the development process of scientific and commercial distributed applications Putting Research to Work in Quality Improvement and Quality Assurance ,1993 This document has the background papers from the 1992 AHCPR conference held to formulate a research agenda for quality assurance and improvement Contents Executive summary A perspective on quality assurance research Quality improvement quality assurance taxonomy a framework Organisational issues and perspectives on quality assurance Quality assurance and quality improvement in the information age Using information in quality improvement and quality assurance What is quality improvement a report from the field Quality improvement a patient s perspective Closing quality improvement assurance information gaps AHCPR s role Closing quality improvement assurance information gaps public and private sector roles Workshop recommendations Appendices

Fundamentals of Computation Theory Erzsébet Csuhaj-Varjú,Zoltán Ésik,2007-08-28 This book features the refereed proceedings of the 16th International Symposium on Fundamentals of Computation Theory Thirty nine full papers are presented along with four invited papers The papers address all current topics in computation theory including automata and formal languages design and analysis of algorithms computational and structural complexity semantics logic circuits and networks learning theory and more *Handbook of Research on User Interface Design and Evaluation for Mobile Technology* Lumsden, Joanna,2008-02-28 This book compiles authoritative research from scholars worldwide covering the issues surrounding the influx of information technology to the office environment from choice and effective use of technologies to necessary participants in the virtual workplace Provided by publisher **The Oxford Handbook of Affective Computing** Rafael A. Calvo,Sidney D'Mello,Jonathan Gratch,Arvid Kappas,2015-01-15 Affective Computing is a growing multidisciplinary field encompassing computer science engineering psychology education neuroscience and many other disciplines It explores how affective factors influence interactions between humans and technology how affect sensing and affect generation techniques can inform our understanding of human affect and on the design implementation and

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transformations can occur as a result of nuclear decay of radioactive isotopes or neutron capture neither procedure requires a change in the atom s element an atom gets transmuted into an atom of a different element when the number of protons in it is changed

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nuclear chemistry is the subfield of chemistry dealing with radioactivity nuclear processes such as nuclear transmutation and nuclear properties it is the chemistry of radioactive elements such as the actinides radium and radon together with the chemistry associated with equipment such as nuclear reactors which are designed to perform

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unlike a normal chemical reaction that forms molecules nuclear reactions result in the transformation of one element into another this property of nuclear reactions is used in nuclear power plants to gather nuclear energy the three common types of radiations are explained below

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a nuclear reactor consists of the following a nuclear fuel a fissionable isotope must be present in large enough quantities to sustain a controlled chain reaction the radioactive isotope is contained in tubes called fuel rods a moderator

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transmutation the changing of one chemical element into another transmutation involves a change in the nucleus or core of an atom and is therefore a nuclear reaction transformations may result from nuclear decay of radioactive isotopes or they can result from neutron capture

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in all accelerators the particles move in a vacuum to avoid collisions with gas molecules when neutrons are required for transmutation reactions they are usually obtained from radioactive decay reactions or from various nuclear reactions occurring in nuclear reactors

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nuclear reaction a nuclear reaction is a process in which two nuclei or a nucleus and an external subatomic particle collide to produce one or more new nuclides the nuclear reaction is a reaction that involves nucleoids the reactant nucleoid called the parent nucleoid usually transforms into a different nucleoid called the daughter

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