Lecture Notes in Bioengineering

Veerendra Kumar
Mukta Bhatele *Editors*

Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012)

Springer

Lecture Notes in Bioengineering

For further volumes:
http://www.springer.com/series/11564

Veerendra Kumar · Mukta Bhatele
Editors

Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012)

Springer

Editors
Veerendra Kumar
Jabalpur Engineering College
Jabalpur, Madhya Pradesh
India

Mukta Bhatele
Computer Science
Gyan Ganga College of Technology
Jabalpur, Madhya Pradesh
India

ISSN 2195-271X ISSN 2195-2728 (electronic)
ISBN 978-81-322-0969-0 ISBN 978-81-322-0970-6 (eBook)
DOI 10.1007/978-81-322-0970-6
Springer New Delhi Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012952004

© Springer India 2013
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

The Institution of Engineers (India) came up with the idea of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012) to be held on 3rd and 4th of November 2012. AISOBE 2012 is an attempt to bring forward the latest research in the fields of bio-medical engineering, information technology, and soft computing. Our vision behind organizing this seminar was to provide a platform to bring researchers and practitioners together including engineers, biologists, health professionals and informatics/computer scientists, to create an integrated environment for personnel interest in both theoretical advances and applications of information systems, artificial intelligence, signal processing, electronics and other engineering tools in knowledge areas related to biology and medicine.

Biomedical engineering is the application of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine: it combines the design and problem-solving skills of engineering with medical and biological sciences to improve healthcare diagnosis, monitoring and therapy.

Thanks to our authors who had submitted papers related to the fields of medicine, computing and image processing all complying with the theme of the seminar.

We were obliged with the presence of renowned medical practitioners who enlightened us with their research in fields like treatment of arachnoid cyst, stereolithography and health monitoring.

We had topics in the field of nanoparticles and nanotechnology and its use in medicine. We had papers about development of medicinal drugs for cancer treatment.

Some papers depicted the use of image processing in the field of biomedical engineering, covering topics like analysis of CT images of bones, analysis of EEG signals, and enhancement of medical image security using digital watermarking, registration, de-noising and compression of medical images.

Numerous papers were related to soft computing, which provided us information about how computing can take advantages from biology by creating computer systems based on human immune system, human cells, etc. Some interesting researches related to genetic algorithm and neural networks were also presented.

We had research papers about wireless sensor networks, MANETs and VANETs, and how these technologies can help in the field of medicine. Some papers were about software used in hospitals and in the field of medicine.

We also enjoyed the presence of few inter-disciplinary research topics from the field of information technology, which are providing their services to the fields of medicine and engineering.

Acknowledgment

AISOBE 2012 is a result of a collective and collaborative endeavor of many individuals and organizations. This acknowledgment is an attempt at thanking all of those who have made it possible.

First and foremost our heartiest thanks to The Institution of Engineers (India) (IEI) for hosting and organizing this seminar and praiseworthy effort of all the members of IEI and office staff at Jabalpur Local Centre (JLC).

We sincerely thank all the authors who were part of this seminar and enlightened us with their work related to theme of the seminar. We are thankful to the management and faculty members at Jabalpur Engineering College, Jabalpur, for their support. We are also grateful to Er. D. C. Jain, Mr. Rajneet Jain, Dr. Maneesh Choubey and all faculty members of Gyan Ganga Group of Institutes Jabalpur. Similarly we are grateful to Shri Ram Group of institutes, Jabalpur for their support.

We would like to thank Dr. I. K. Bhat, Dr. A. D. Bhat, Dr. A. M. Kuthe, Dr. R. K. Shrivastava, Dr. K. Pandesar, Dr. Puneet Tandon, Dr. Rajesh Dhiravani, Dr. Jitendra Jamdar, Dr. Pushpraj Bhatele, Dr. Parimal Swamy, Dr. Arun Sharma, Dr. Tapas Chakma, Dr. H. K. T. Raza, Dr. Y. R. Yadav and Dr. D. P. Lokwani for reviewing the papers. We would also like to thank the management and doctors at Jabalpur Hospital Pvt Ltd, Jamdar Hospital Pvt Ltd and Apex Hospital, Jabalpur.

We express our gratitude toward Mr. S. L. Garg, FIE President, Dr. R. K. Dave, Mr. Suneel Grover, Mr. V. K. Gupta, Dr. M. Selot and Mr. K. C. Sethi, who are respected members of our National Advisory Committee and to Er. Rakesh Rathore, Er. Raman Mehta and Er. P. S. Naidu, who are respected members of Executive Committee JLC, IEI. We are also very grateful to Dr. Veerendra Kumar, Convener and Er. Mukta Bhatele, Organizing Secretary, AISOBE 2012.

We appreciate Springer India Pvt Ltd, especially Mr. Yumnam Ojen Singh and his team at Springer for publishing presented papers in *Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012)*.

Finally, we would like to thank everyone who attended the seminar and made it success, and it is very likely that we had missed some names; therefore, we are grateful to everyone who has directly or indirectly catered to this seminar.

Contents

Expert List

National Advisory Committee

Chairman
Mr. S. L. Garg, FIE President, IEI

Co-Chairman
Dr. R. K. Dave, FIE Chairman, ICC, IEI
Mr. Suneel Grover, Member, ICC, IEI
Mr. V. K. Gupta, Member, ICC, IEI
Dr. M. Selot, Member, ICC, IEI
Mr. K. C. Sethi, Member, ICC, IEI

Convener
Dr. Veerendra Kumar

Organizing Committee

Chairman
Mr. Rakesh Rathore, FIE, Chairman, JLC, IEI

Organising Secretary
Er. Mukta Bhatele

Honorary Secretary
Mr. Raman Mehta, FIE

Joint Org. Secy
Er. P. S. Naidu, FIE

Members
Mr. N. K. Mehta, Mr. S. K. Tiwari,
Mr. Laxman Das, Mr. B. S. Baghel,
Mr. R. K. Chouksey, Mr. V. K. Sahu,
Mr. M. K. Raghuvanshi, Mr. K. K. Jain,
Dr. I. K. Khanna, Mr. V. K. Birthire,
Mr. V. K. Pandya, Dr. P. S. Bundella,
Col R. S. Malhotra

Editor-in-Chief
Dr. Veerendra Kumar

Editors
Dr. Mukta Bhatele
Dr. J. S. Yadav
Dr. Neetu Bhatia

Technical Committee
Dr. I. K. Bhat
Dr. A. D. Bhat
Dr. A. M. Kuthe
Dr. R. K. Shrivastava
Dr. K. Pandesar
Dr. Puneet Tandon
Dr. Rajesh Dhiravani
Dr. Jitendra Jamdar
Dr. Pushpraj Bhatele
Dr. Tapas Chakma
Dr. H. K. T. Raza
Dr. Y. R. Yadav
Dr. D. P. Lokwani
Prof. (Dr.) D. C. Chaurasia

Special Invitees
Dr. N. R. Bandyopadhyay
Dr. U. Chandrasekhar
Dr. Pradeep Chaturvedi
Dr. G. S. Yadava
Lt. Gen. (Dr.) V. J. Sundaram
Prof. (Dr.) T. S. Kamal
Mr. P. K. Maity
Mr. A. K. Saxena
Prof. S. Radhakrishnan
Dr. Sanjeev Banerjee
Dr. Parimal Swamy
Dr. Parvez Siddiqui
Dr. Ajay Seth
Dr. Anant Joshi
Dr. Bhavin Jahnkaria
Dr. Sanjay Pandey
Dr. Yugal Mishra
Dr. Chandrashekhar Niyogi
Dr. N. P. Gupta
Dr. Prashant Jain

About the Editors

Prof. Veerendra Kumar is currently the Principal of Jabalpur Engineering College, India. Earlier to this, he was the Dean (Planning and Evaluation) of the college from June 2010 to July 2012. He was also the Head of the Department of Mechanical Engineering from December 2008 to July 2012. He has more than 25 years of experience in teaching and training. Prof. Kumar has recently submitted a Ph.D. thesis on Biomechanics to the National Institute of Technology, Hamirpur, India. He is an M.E. in Machine Design (completed in 1985) from Rani Durgavati Vishwavidyalaya, Jabalpur. In 1982, he completed B.E. in Mechanical Engineering from University of Jabalpur, Jabalpur. His areas of specialization include Biomechanics, Machine Design, Finite Element Method, and Computer Aided Design. Professor Kumar has published a book titled "A Textbook of Industrial Robotics" in 2010 with Dhanpat Rai Publishing Company (P) Limited, New Delhi and 13 papers in international journals. He was Editor of the Proceedings of National Seminar on Role of Information Technology in 21st Century, February 11 and 12, 1999 at Government Engineering College, Jabalpur. He is a Life Member of the Indian Society for Technical Education and the Association for Machines and Mechanisms, and a Member of The Institution of Engineers (India).

Prof. (Mrs) Mukta Bhatele is currently a faculty member in the Computer Science and Engineering Department of Gyan Ganga College and Technology, Jabalpur. She holds B.E. and M.Tech. degrees from Maulana Azad National Institute of Technology (previously Maulana Azad College of Technology), Bhopal. She has more than 17 years of experience as a teacher. She has 10 publications in renowned international journals and numerous publications in national level journals and conferences. She is currently the Honorary Secretary of The Institution of Electronics and Telecommunication Engineers, Jabalpur Centre and a Member of The Institution of Engineers (India).

Stereolithography: A Recent Tool in Diagnosis, Treatment Planning, and Management of Craniofacial Deformities

Rajesh B. Dhirawani

Abstract Medical rapid prototyping (MRP) is defined as the manufacture of dimensionally accurate physical models of human anatomy derived from medical image data using a variety of rapid prototyping (RP) technologies. It has been applied to a range of medical specialties, including oral and maxillofacial surgery [1–7], dental implantology, neurosurgery [8, 9], and orthopedics [10, 11]. The source of image data for 3-dimensional (3D) modeling is principally computed tomography (CT), although magnetic resonance imaging and ultrasound have also been used. Medical models have been successfully built of hard tissue (bone) and soft tissues (blood vessels and nasal passages). MRP was described originally by Mankowich et al. in 1990 [12].

Keywords Stereolithography · Maxillofacial surgery · Dental implantology

Stereolithography

An SL RP system consists of a bath of photosensitive resin, a model-building platform, and an ultraviolet (UV) laser for curing the resin. Figure 1 shows the principle of operation of SL apparatus. A mirror is used to guide the laser focus onto the surface of the resin, where the resin becomes cured when exposed to UV radiation. The mirror is computer controlled, with its movement being guided to cure the resin on a slice-by-slice basis. A model is initially designed with CAD

R. B. Dhirawani (✉)
Director at Jabalpur Hospital & Research Centre, Jabalpur, India

R. B. Dhirawani
Director at Hitkarini Dental College & Hospital, Jabalpur, India

V. Kumar and M. Bhatele (eds.), *Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012)*, Lecture Notes in Bioengineering,
DOI: 10.1007/978-81-322-0970-6_1, © Springer India 2013

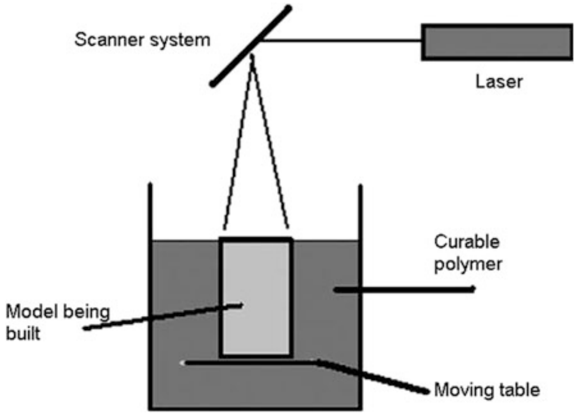

Fig. 1 Diagram showing the principle of operation of an SL system. Winder and bibb. Medical rapid prototyping technologies. J Oral Maxillofac Surg 2005

software in a suitable file format (commonly STL) and transferred to the SL machine for building. The CAD data file is converted into individual slices of known dimensions. This slice data are then fed to the RP machine, which guides the exposure path of the UV laser onto the resin surface. The layers are cured sequentially and bond together to form a solid object beginning from the bottom of the model and building up. As the resin is exposed to the UV light, a thin well-defined layer thickness becomes hardened. After a layer of resin is exposed, the resin platform is lowered within the bath by a small known distance. A new layer of resin is wiped across the surface of the previous layer using a wiper blade, and this second layer is subsequently exposed and cured. The process of curing and lowering the platform into the resin bath is repeated until the full model is complete. The self-adhesive property of the material causes the layers to bond to one another and eventually form a complete, robust, 3D object. The model is then removed from the bath and cured for a further period of time in a UV cabinet Fig. 2. The built part may contain layers, which significantly overhang the layers below. If this is the case, then a network of support structures, made of the same material, is added beneath these overhanging layers at the design stage to add support during the curing process. These support structures, analogous to a scaffold, are removed by hand after the model is fully cured. This is a labor-intensive and time-consuming process. Generally, SL is considered to provide the greatest accuracy and the best surface finish of any RP technology. The model material is robust, slightly brittle, and relatively light, although it is hydroscopic and may physically warp over time (a few months) if exposed to high humidity.

Continued advances in biomodeling can facilitate better diagnosis, treatment planning, and fabrication of implants for craniomaxillofacial surgeries. Clinically, these models are used mainly for craniofacial deformities, reconstructive surgeries, pathologies, and trauma [13]. Biomodels generated by stereolithography (SL) have been confirmed to have a higher accuracy compared with milled models and 3-dimensional (3D) computed tomography (CT) visual models [14, 15].

The technology allows production of highly accurate and realistic replicas of the body structures of an individual. The literature has shown some promising

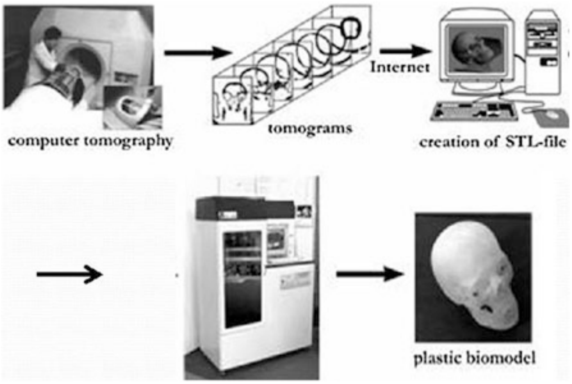

Fig. 2 The pictorial presentation of the complete process of fabrication of a stereolithographic model

results using a stereolithographic model as a guide for reconstruction [16–19]. Facial asymmetry, when obvious, has enormous socio-psychological impact on the affected individuals. It can occur as a consequence of developmental anomalies or disease or after trauma or surgery. Surgical reconstruction is usually indicated in most instances involving a noticeable facial asymmetry. In such surgeries the use of a rapid prototype technique—SL can help yield accurate, esthetic, and desired results.

SL models have the following range of applications:

- To aid production of a surgical implant
- To improve surgical planning
- To act as an orienting aid during surgery
- To enhance diagnostic quality
- To be useful in preoperative simulation
- To achieve patient's agreement prior to surgery
- To prepare a template for resection

The technique of color SL was developed very recently. This technique allows the selective coloring of structures in the 3D solid model. The 3D information of a solid model combined with the extra information from the selective coloring of certain anatomical structures both combine as an ultimate diagnostic and preoperative planning tool [20].

Clinical Applications

Traumatology

Stereolithographic models in trauma cases have proven to be useful in terms of visualizing the bony displacement, facilitating anatomical reduction, minimizing surgical approaches, and saving operating time [14]. Due to surgery simulation it

Fig. 3 Pre-operative frontal bone defect

Fig. 4 Stereolithographic model of the patient

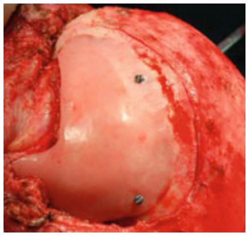

Fig. 5 Intraoperative picture showing fixation of the acrylic implant

Fig. 6 Intraoperative correction of defect

becomes possible to adjust prefabricated mini- or microplates in the patient as in the preoperative planning. The configuration and bending of the plates also acts as a device for the anatomical reduction of the fragments. However, in case of comminution with very small fragments, surgery simulation with complete reduction on the 3D model is not advisable [21].

A case was done at our center, where the patient had a frontal bone defect due to trauma. A stereolithographic model was fabricated which facilitated in the visualization of defect in 3D, proper assessment of the injury, and aided in the fabrication of acrylic prosthesis to correct the defect (Figs. 3, 4, 5, 6, 7).

Fig. 7 Postoperative picture showing correction of the deformity and facial symmetry

Tumor Surgery

Preoperative model planning by color SL is useful in ablative surgery of tumors of the craniofacial region. The coloring of the tumor clarifies its relation to surrounding structures and illustrates eventual extension in the adjacent tissue. The main advantages of this technique are visualization of the problem, planning of the surgical approach, and determination of extent of the resection in areas of complex anatomy.

Reconstructive Surgery

Surgery simulation is helpful in primary reconstruction of maxillofacial defects and estimation of the amount of graft required for the reconstruction. Proper placement of the graft in the exact position can be accurately determined. Even plates can be prefabricated to hold the future bone graft. The precise fitting implants facilitate surgery thus saving operating time.

Trauma, cranial bone tumors, and congenital anomalies are the main reasons for craniofacial defects. The main indications for reconstruction of these defects are cosmetic reasons and protection of intracranial structures (Fig. 8).

Advantages

- Plate handling in the operating theater is minimal, thus preserving its strength.
- Decreased exposure time to general anesthesia.
- Decreased blood loss.
- Shorter wound exposure time [22].

Craniofacial Surgery

Craniosynostoses is the term that designates premature fusion of one or more sutures in either the cranial vault or cranial base. The disparity between intracranial volume and brain volume may increase intracranial pressure. The goals of

Fig. 8 Stereomodel used for adaptation of titanium plate

surgery of the newborn with a craniosynostosis are twofold: (1) Decompression of the intracranial space (to reduce intracranial pressure, to prevent visual problems, and to permit normal mental development) and (2) Achievement of satisfactory craniofacial form. The different methods of osteotomy for cranial vault remodeling can be simulated on the 3D model. The introduction of SL for cranioplasty of newborns and infants has reduced operating time significantly [22].

Distraction Osteogenesis

Stereomodels have proven to be highly beneficial in cases of distraction osteogenesis. They help in the planning, positioning of the device, placement of the osteotomy cuts, and predicting and visualizing the end results of the treatment. They also help in patient education and better understanding of the treatment procedure.

Conclusion

- The use of 3D models in oral and maxillofacial surgery has significantly improved predictability of clinical outcomes when compared to similar treatments without its use.
- Total operating time is reduced which has the benefit of decreasing the duration of general anesthesia and reducing wound exposure time.
- Assessment of extensive traumatic and pathologic defects in three-dimensions prior to surgical reconstruction.
- The models are useful in the design and fabrication of custom prosthesis and sizing of bone grafts, distraction osteogenesis, and patient education.

References

1. Anderl H, Zur Nedden D, Muhlbauer W et al (1994) CT-guided stereolithography as a new tool in craniofacial surgery. Br J Plast Surg 47:60
2. Arvier JF, Barker TM, Yau YY et al (1994) Maxillofacial biomodelling. Br J Oral Maxillofac Surg 32:276
3. D'Urso PS, Barker TM, Earwaker WJ et al (1999) Stereolithographic biomodelling in cranio-maxillofacial surgery: a prospective trial. J Craniomaxillofac Surg 27:30
4. Eufinger H, Wehmoller M (1998) Individual prefabricated titanium implants in reconstructive craniofacial surgery: clinical and technical aspects of the first 22 cases. Plast Reconstr Surg 102:300
5. Gateno J, Allen ME, Teichgraeber JF et al (2000) An in vitro study of the accuracy of a new protocol for planning distraction osteogenesis of the mandible. J Oral Maxillofac Surg 58:985
6. Sailer HF, Haers PE, Zollikofer CP et al (1998) The value of stereolithographic models for preoperative diagnosis of craniofacial deformities and planning of surgical corrections. Int J Oral Maxillofac Surg 27:327
7. Hughes CW, Page K, Bibb R et al (2003) The custom made orbital floor prosthesis in reconstruction for orbital floor fractures. Br J Oral Maxillofac Surg 41:50
8. Winder RJ, Cooke RS, Gray J et al (1999) Medical rapid prototyping and 3D CT in the manufacture of custom made cranial titanium plates. J Med Eng Tech 23:26
9. Heissler E, Fischer F, Bolouri S et al (1998) Aesthetic and reconstructive surgery: custom-made cast titanium implants produced with CAD/CAM for the reconstruction of cranium defects. Int J Oral Maxillofac Surg 27:334
10. Mankovich NJ, Cheeseman AM, Stoker NG (1990) The display of three-dimensional anatomy with stereolithographic models. J Digit Imaging 3:200
11. Cheung LK, Wong MC, Wong LL (2002) Refinement of facial reconstructive surgery by stereo-model planning. Ann R Australas Coll Dent Surg 16:129
12. Lill W, Solar P, Ulm C et al (1992) Reproducibility of three-dimensional CT-assisted model production in the maxillofacial area. Br J Oral Maxillofac Surg 30:233
13. Klein HM, Schneider W, Alzen G et al (1992) Pediatric craniofacial surgery: comparison of milling and stereolithography for 3D model manufacturing. Pediatr Radiol 22:458
14. Kermer C, Linder A, Friede I et al (1998) Preoperative stereolithographic model planning for primary reconstruction in craniomaxillofacial trauma surgery. J Craniomaxillofac Surg 26:136
15. Holck DEE, Boyd EM, Ng J et al (1999) Benefits of stereolithography in orbital reconstruction. Ophthalmology 106:1214
16. Kernan BT, Wimsatt JA (2000) Use of a stereolithography model for accurate, preoperative adaptation of a reconstruction plate. J Oral Maxillofac Surg 58:349
17. Eppley BL (2002) Craniofacial reconstruction with computer-generated HTR patient-matched implants: use in primary bone tumor excision. J Craniofac Surg 13:650
18. Tada H, Hatoko M, Tanaka A et al (2002) Preshaped hydroxyapatite tricalcium-phosphate implant using three-dimensional computer tomography in the reconstruction of bone deformities of craniomaxillofacial region. J Craniofac Surg 13:287
19. Wong Tung-Yiu, Fang Jing-Jing, Chung Ching-Hung et al (2005) Comparison of 2 methods of making surgical models for correction of facial asymmetry. J Oral Maxillofac Surg 63:200–208
20. Bill J, Reuther J, Dittmann W, Kübler N, Meier J, Pistner H, Wittenberg G (1995) Stereolithography in oral and maxillofacial operation planning. Int J Oral Maxillofac Surg 24:98–103
21. Kärcher H (1992) Three-dimensional craniofacial surgery: transfer from a three-dimensional model (Endoplan) to clinical surgery: a new technique (Graz). J Cranio-Max Fac Surg 20:125–131
22. Lambrecht JT (1989) Planning orthognathic surgery with three dimensional models. Int J Adult Orthodon Orthognath Surg 4:141–144

Image Denoising by Data Adaptive and Non-Data Adaptive Transform Domain Denoising Method Using EEG Signal

Vandana Roy and Shailja Shukla

Abstract This chapter proposes an automatic method for artifact removal and noise elimination from scalp electroencephalogram recordings (EEG). The method is based on transform domain method having combination of data adaptive and non-data adaptive transform domain image denoising method to improve artifact elimination (ocular, high frequency muscle, and electrocardiogram (ECG) artifacts). The elimination of artifact from scalp EEGs is of substantial significance for both the automated and visual examination of underlying brainwave actions. These noise sources increase the difficulty in analyzing the EEG and obtaining clinical information related to pathology. Hence it is crucial to design a procedure to decrease such artifacts in EEG records. The role of a data adaptive transform domain, i.e., ICA to separate the signal from multichannel sources, then non-data adaptive transform, i.e., wavelet is applied to denoise the signal. The proposed methodology successfully rejected a good percentage of artifacts and noise, while preserving almost all the cerebral activity. The "denoised artifact-free" EEG presents a very good improvement compared with recorded raw EEG.

Keywords Artifact removal · Electroencephalogram (EEG) · Wavelet denoising · Independent component analysis (ICA)

V. Roy (✉)
Department of Electronics and Communication, Jabalpur Engineering College, Jabalpur, Madhya Pradesh, India
e-mail: vandana.roy20@gmail.com

S. Shukla
Department of Computer Science Engineering, Jabalpur Engineering College, Jabalpur, Madhya Pradesh, India

V. Kumar and M. Bhatele (eds.), *Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOBE 2012)*, Lecture Notes in Bioengineering,
DOI: 10.1007/978-81-322-0970-6_2, © Springer India 2013

Introduction

The electrical activity produced by the brain is recorded by the electroencephalogram (EEG) using several electrodes placed on the scalp. Signal characteristics vary from one state to another, such as wakefulness/sleep or normal/pathological. EEG is the multivariate time series data measured using multiple sensors positioned on the scalp that imitates electrical potential produced by behaviors of brain and is a record of the electrical potentials created by the cerebral cortex nerve cells. There are two categories of EEG based on where the signal is obtained in the head: scalp or intracranial. Scalp EEG being the main focus of the research, uses small metal discs, also called electrodes, which are kept on the scalp with good mechanical and electrical touch. Intracranial EEG is obtained by special electrodes placed in the brain during a surgery. The electrodes should be of low impedance in order to record the exact voltage of the brain neuron. The variations in the voltage difference among electrodes are sensed and amplified before being transmitted to a computer program [1]. Classically, five major brain waves can be distinguished by their frequency ranges: delta (δ) 0.5–4 Hz, theta (θ) 4–8 Hz, alpha (α) 8–13 Hz, beta (β) 13–30 Hz and gamma (γ) 30–128 Hz. The informative cortically generated signals are contaminated by extra-cerebral artifact sources: ocular movements, eye blinks, electrocardiogram (ECG), muscular artifacts. Generally, the mixture between brain signals and artifactual signals is present in all sensors, although not necessarily in the same proportions (depending on the spatial distribution). Moreover, the EEG recordings are also affected by other unknown basically random signals (instrumentation noise, other physiological generators, external electromagnetic activity, etc.) which can be modeled as additive random noise. These phenomena make difficult the analysis and interpretation of the EEGs, and a first important processing step would be the elimination of the artifacts and noise. Several methods for artifact elimination were proposed. Most of them consist of two main steps: artifact extraction from the multichannel recorded signals, generally using some signal separation methods, followed by signal classification. Our goal is to contribute to EEG artifact rejection by proposing an original and more complete automatic methodology consisting of an optimized combination of several signal processing and data analysis techniques [2].

This chapter is organized as follows: Supporting Literature briefs the supporting literature, Data Adaptive Transform Domain Image Denoising Method: ICA states the data adaptive transform domain method to separate the signals from multichannel sources, then Non Data Adaptive Transform Domain Based Denoising (Wavelet denoising) gives details of non-data adaptive transform domain method to denoise the signal to remove artifacts. This method assumes that EEG contains two classes namely, artifact and non- artifact signal, and then it calculates the optimum threshold separating these two classes. Proposed Method is dedicated to our present approach to denoise the signal and Experimental Results presents the main results in Sect. 6.

Supporting Literature

EEG Signals: The nervous system sends commands and communicates by trains of electric impulses. When the neurons of the human brain process information they do so by changing the flow of electrical current across their membranes. These changing currents (potential) generate electric fields that can be recorded from the scalp. Studies are interested in these electrical potentials but they can only be received by direct measurement. This requires a patient to undergo surgery for electrodes to be placed inside the head. This is not acceptable because of the risk to the patient. Researchers therefore collect recordings from the scalp receiving the global descriptions of the brain activity. Because the same potential is recorded from more than one electrode, signals from the electrodes are supposed to be highly correlated. These are collected by the use of an electroencephalograph and are called EEG signals. Understanding the brain is a huge part of Neuroscience, and the development of EEG was for the explanation of such a phenomenon. The morphology of EEG signals has been used by researches and in clinical practice to:

- Diagnose epilepsy and see what type of seizures is occurring.
- Produce the most useful and important test in conforming a diagnosis of epilepsy.
- Check for problem with loss of consciousness or dementia.
- Help find out a person's chance of recovery after change in consciousness.
- Find out whether a person is in coma or is brain dead.
- Study sleep disorder such as narcolepsy.
- What brain activity occurs while a person is receiving general anesthesia during brain surgery.
- Help find out whether a person has a physical problem (in the brain, spinal cord, or nervous system) or a mental health problem.

The signals must therefore present a true and clear picture of brain activities. Being a physical system, recording electrical potentials present EEG with problems; all neurons, including those outside the brain, communicate using electrical impulses. These non-cerebral impulses are produced from:

- Eye movement and blinking—Electrooculogram (EOG)
- Cardiac movement—Cardiograph (ECG/EKG)
- Muscle movement—Electromyogram (EMG)
- Chewing and sucking movement—Glassokinetic
- The power lines.

EEG recordings are therefore a combination of these signals called artifacts or noise and the pure EEG signal defined mathematically as in Eq. (1):

$$E(t) = S(t) + N(t) \tag{1}$$

where,
S is pure EEG signal,

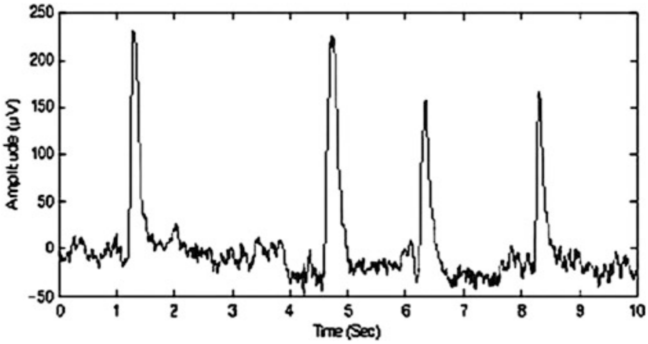

Fig. 1 EEG contaminated with EOG producing spikes

N is the noise and
E represents the recorded signal.

The presence of these noises introduces spikes which can be confused with neurological rhythms. They also mimic EEG signals overlying these signals resulting in signal distortion (Fig. 1). Correct analysis is therefore impossible, resulting in misdiagnosis in the case of some patients. Noise must be eliminated or attenuated.

The method of cancellation of the contaminated segments, although practice can lead to considerable information loss, thus other methods such as principal component analysis (PCA) and more recently ICA and WT have been utilized [3].

Data Adaptive Transform Domain Image Denoising Method: ICA

Definitions of ICA: We can define the ICA as it is a random vector X which consists of finding a linear transform as in Eq. (2):

$$X = AS \tag{2}$$

so that the components s_i are as independent as possible w.r.t. some maximum function that measures independence. This definition is known as a general definition where no assumptions on the data are made. Independent component analysis (ICA) is the decomposition of a random vector in linear components which are "as independent as possible". Here, 'independence' should be understood in its strong statistical sense: it goes beyond second order decorrelation and thus involves the non-gaussianity of the data. The ideal measure of independence is the higher order cumulants like kurtosis and mutual information.

In addition to the basic assumption of statistically independence, by imposing the following fundamental restrictions, the noise free ICA model can be defined if:

1. All the independent components S_i, with the possible exception of one component, must be non-Gaussian
2. The number of observed linear mixtures m must be at least as large as the number of independent components n, i.e., $m > p$
3. The matrix A must be of full column rank.

We can invert the mixing matrix as in Eq. (3):

$$S = A^{-1} X \tag{3}$$

Thus, to estimate one of the independent components, we can consider a linear combination of X_i Let us denote this by Eq. (4):

$$Y = b^T X = b^T AS \tag{4}$$

Hence, if b were one of the rows of A^{-1}, this linear combination $b^T X$ would actually equal one of the independent components. But in practice we cannot determine such 'b' exactly because we have no knowledge of matrix A, but we can find an estimator that gives a good approximation. In practice there are two different measures of non-Gaussianity.

Kurtosis

The classical measure of non-Gaussianity is kurtosis or the fourth order cumulant. It is defined by Eq. (5)

$$\text{Kurt}\ (y) = E\{y^4\} - 3\left(E\{y^2\}\right)^2 \tag{5}$$

As the variable y is assumed to be standardized we can say in Eq. (6) as:

$$\text{Kurt}\ (y) = E\ \{\ y4\} - 3 \tag{6}$$

Hence the kurtosis is simply a normalized version of the fourth moment E{y4}. For the Gaussian case the fourth moment is equal to 3 and hence kurt (y) = 0. Thus, for Gaussian variable kurtosis is zero but for non-Gaussian random variable it is nonzero [4, 5].

Non-Data Adaptive Transform Domain-Based Denoising (Wavelet Denoising)

We know that Fast ICA are expected to correspond to artifacts only, on the other hand, some brain action might escape to these gathered signals. The purpose of conventional filtering is to process raw EEG data x(t) to eliminate 50 Hz line noise, baseline values, artifacts inhabiting very low frequencies and high frequency sensor noise v(t), and this phase may include mixture of different existing notch, lowpass, and/or highpass filters. As artifacts have a frequency overlap with the brain signals, the conventional filtering technique cannot be utilized, and therefore this paper focuses on using Wavelet Denoising to explore brain activity from gathered independent components [1].

Image signal and noise signal by the wavelet transform have different characteristics:

1. In the wavelet transform, the noise energy reduces rapidly as scale increases, but the image signal does not reduce rapidly.
2. Noise is not highly relevant at different scales of the wavelet transform. But the wavelet transform of image signal generally has a strong correlation, the scale of the adjacent local maxima almost appear in the same position and have the same symbol.

The two above-mentioned points will separate image signal and noise signal, that is to say they are the base of image denoising [6].

Wavelet Domain-Based Denoising Algorithm

An image is often corrupted by noise in its acquisition or transmission. Wavelet provides an appropriate basis for separating noisy signal from image signal. The motivation is that as the wavelet transform is good at energy compaction, small coefficient is more likely due to noise and large coefficient due to important signal features. These small coefficients can be threshold without affecting the significant features of the images.

The problem that arises is how to find an optimal threshold such that the mean squared error between the signal and its estimate is minimized. The wavelet decomposition of an image is done as the image is split into 4 subbands, namely the HH, HL, LH, and LL subbands as shown in Fig. 2. The HH subband gives the diagonal details of the image; the HL subband gives the horizontal features while the LH subband represents the vertical structures. The LL subband is the low resolution residual consisting of low frequency components and it is this subband which is further split at a higher level of decomposition as shown in Fig. 2 [7].

The low pass filters represent the “approximation” of the signal or its dc component and the high pass filters represent the “details” or its high frequency

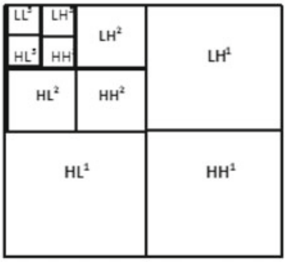

Fig. 2 Wavelet decomposition: 1, 2, 3 decomposition levels, *H* high frequency bands, *L* low frequency bands

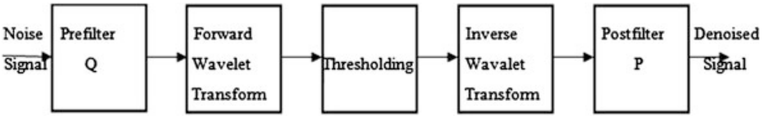

Fig. 3 Denoising by wavelet domain

components. The successive analysis of the low pass component only is called wavelet decomposition, (Fig. 1b), whereas the analysis of both the low and high pass components is called wavelet packet decomposition; the existence of small coefficients is more likely to be due to the noise contamination, whereas the large coefficients contain significant image details. Hence, the small magnitude coefficients may be thresholded without affecting the large ones and therefore the quality of the image [8].

The investigations show that themethod for denoising differs only in the selection of the wavelets and their decomposition levels [6].

The algorithm has the following steps:

1. Calculate the DWT of the image.
2. Threshold the wavelet coefficients (Threshold may be universal or subband adaptive).
3. Compute the IDWT to get the denoised estimate.

Wavelet transform of noisy signal should be taken first and then thresholding function is applied on it. Finally the output should be undergone inverse wavelet transformation to obtain the estimate x as shown in Fig. 3.

The DWT of any signal sample is given by Eq. (7)

$$S_{\mathrm{DWT}}(j,k) = \sum_{n=0}^{N-1} S_{nj,k}\, w_n, \quad a = 2^j,\ \tau = k2^j \tag{7}$$

S_n s(nT) Signal samples
$j,k\ W_n$ nth sample of kth sifted version of a 2^j scaled discrete wavelet
N number of signal samples.

There are four thresholds frequently used, i.e., hard threshold, soft threshold, semi-soft threshold, and semi-hard threshold. The hard-thresholding function keeps the input if it is larger than the threshold, otherwise, it is set to zero. It is described as in Eq. (8)

$$\begin{aligned} f_h(x) &= x \quad \text{if } x \geq \lambda \\ &= 0 \quad \text{otherwise} \end{aligned} \tag{8}$$

The hard-thresholding function chooses all wavelet coefficients that are greater than the given threshold $\lambda\ \psi$ and sets the others to zero. The threshold λ is chosen according to the signal energy and the noise variance 2σ. If a wavelet coefficient is greater than λ, we assume that as significant and attribute it to the original signal. Otherwise, we consider it to be due to the additive noise and discard the value. The soft-thresholding function has a somewhat different rule from the hard-thresholding function. It shrinks the wavelet coefficients by $\lambda\ \psi$ toward zero, which is the reason why it is also called the wavelet shrinkage function. It is explained in Eq. (9) as:

$$\begin{aligned} f_s(x) &= x - \lambda \quad \text{if} x > \lambda \\ &= 0 \quad \text{if} x < \lambda \\ &= x\ +\ \lambda \quad \text{if} x \leq -\lambda \end{aligned} \tag{9}$$

The soft-thresholding rule is chosen over hard-thresholding, as the soft-thresholding method yields more visually pleasant images over hard-thresholding.

Then finally IDWT is calculated by Eq. (10)

$$s_n = \frac{1}{N} \sum_{j=0}^{log_2 N} \sum_{k=0}^{int(N/2^{j+1})} S_{j,k} j, kw_n \tag{10}$$

where
$j,\ kw_n$ nth sample of kth sifted version of a 2^j scaled discrete wavelet
J,k row index
n column index [8].

In our work we have used OTSU'S thresholding to denoise the image which chooses the threshold in such a way that all variances available in black and white pixels in the same signal are minimized.

level = graythresh (I) computes a global threshold (level) that can be used to convert an intensity image into a binary image with im2bw. level is a normalized intensity value that lies in the range [0, 1].

The graythresh function uses Otsu's method, which chooses the threshold to minimize the intraclass variance of the black and white pixels.

Multidimensional arrays are converted automatically in to 2D arrays using reshape. The graythresh function ignores any nonzero imaginary part of I.

[level EM] = graythresh (I) returns the effectiveness metric, EM, as the second output argument. The effectiveness metric is a value in the range [0 1] that indicates the effectiveness of the thresholding of the input image. The lower bound is attainable only by images having a single gray level, and the upper bound is attainable only by two-valued images.

Proposed Method

In this chapter we have taken the pure EEG signals having four samples that are then mixed with noise. The signal is processed with ICA and then further with wavelet denoise. ICA is applied so as to separate the signals from a multichannel source of signals and then wavelet denoising to remove noise from an independent component of the signal; we find that the final signal shows better artifacts removal as compared to simple filtering methods. The complete process is explained in the following algorithm:

Algorithm

1. Plot the EEG signal that is mixed with noise with respect to *j* and *k*.
2. Apply conventional filtering through Kurtosis that is defined by Eq. (5):

$$\mathrm{Kurt}(y) = E\{y^4\} - 3\left(E\{y^2\}\right)^2$$

3. Let the original signal be defined by X, then basic ICA model is expressed by Eq. (11)

$$X = AS + N \tag{11}$$

where,

A mixing matrix
S independent component
N noise added

4. To denoise the image using ICA we have to process the image. The preprocessing consists of two steps:

a. Centering: the signal is first centered, i.e., we substract the image mean from the noisy image. It is expressed mathematically as in Eq. (12):

$$X \leftarrow X - E\{X\} \tag{12}$$

b. Whitening: in whitening we remove the second order statistical dependence in the data, i.e., the whitened data have unit variance and they are uncorrelated. Let Z be zero mean random vector, then in terms of covariance matrix we can write

$$\mathrm{E}\left\{\mathrm{ZZ}^{\mathrm{T}}\right\} = \mathrm{I} \tag{13}$$

where I is identity matrix.
Finally whitened data Z is expressed by Eq. (14):

$$\mathrm{Z} = \mathrm{D}^{-1/2}.\mathrm{E}^{\mathrm{T}}.\mathrm{X} \tag{14}$$

where E is matrix whose columns are unit norm eigenvectors of covariance matrix.

$$\mathrm{C}_{\mathrm{X}} = \mathrm{E}\left\{\mathrm{XX}^{\mathrm{T}}\right\} \tag{15}$$

D is diagonal matrix of eigenvalues of C_{X}

5. Using the demixing matrix obtained above we obtain the mixing matrix A by the equation

$$\mathrm{A} = \text{ pseudoinverse } (\mathrm{w}) \tag{16}$$

6. Finally denoised image is obtained by the mixing matrix A and the independent component.
7. Then Otsu's thresholding is done and values below a certain threshold are set to zero.
8. This gives the whitened denoisd image. To reconstruct the image from this we add the mean to this image which was substracted earlier and multiply the whitening matrix to obtain the final denoised image.

Experimental Results

This section presents the evaluation of the proposed artifact removal technique. Initially, EEG signals are captured with occurrence of artifacts. Figure 4 shows the four samples of EEG signal that is effected through noise and artifacts. We defined *n* as the number of iterations and to plot our data to number of values to number of iteration we defined *j* and also *j* as the original matrix value of data and k defines the number of blocks available in data. Then Fig. 5 shows the result using ICA so as to find the independent component. Figure 6 is a result of signal after implementation of wavelet denoising on the signals of Fig. 5. From these figures, it has been observed that the proposed artifact removal technique results in better removal of artifacts. This will help in improving the performance of the further processing of this EEG signal.