Final Report for Period: 09/2009 - 08/2010
Submitted on: 09/30/2010
Principal Investigator: Kang, Sung H.
Award ID: 0908517
Organization: GA Tech Res Corp - GIT
Submitted By:
Kang, Sung - Principal Investigator
Title:
Image Deblurring and Decomposition: Texture and Color Image Analysis

Project Participants

Senior Personnel

Name: Kang, Sung
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

With Berta Sandberg (UCLA) and Tony Chan (UCLA), the PI developed unsupervised multiphase segmentation model.

With Minh Ha-Quang (Humboldt University of Berlin, Germany) and Triet Le (Yale University), the PI studied colorization problem using reproducing Kernel Hilbert space approach.

With Marco Barchiesi (Carnegie Mellon University), Triet Le (Yale), Massimiliasno Morini (SISSA, Italy), Luca Mugnai (University of Leipzig, Germany), Marcello Ponsiglione (University of Rome, Italy), the PI proposed a variation of image segmentation functional which captures the oscillation on the boundary.

With Andy Yip (National University of Singapor) and Berta Sandberg (UCLA), the PI proposed a scale segmentation model related to data clustering.

With Riccardo March, Rome, Italy (r.march@iac.cnr.it), the PI is looking into existence and uniqueness, analysis aspect of the image segmentation functional.

With Jean-Francois Aujol (ENS Cachan, France), the PI is investigating new functionals utilizing the singularities of a well-potential.

With Wei Zhu (U of Alabama) and George Biros (CSE, Georgia Tech), the PI is exploring various applications in medical imaging.

In addtion, some on-going discussions with Stacey Levine (Duquesne University) and Dr. Frank Crosby (US Navy research).

Activities and Findings

Research and Education Activities:

The PI co-organized three sessions of minisymposia with M. Westdickenberg (Math, Georgia Tech) at the SIAM Conference on Analysis of Partial Differential Equation in December 7-10, 2009. The session was titled Variational methods in image processing and interface problem. The first session was focused on theoretical aspects of imaging functionals, the second session on application and various models, and the third session on numerical advances.

The PI also co-organized two sessions with Jean-Francois Aujol (ENS, France) at the SIAM conference on Imaging Science in April 2010. The participants included junior and senior researchers from Europe, Asia and the US, and the research areas ranged from applied analysis to numerical analysis.

Locally, the PI helped to organize the 2nd annual Georgia Scientific Computing Symposium (GSC) which was held at the School of Mathematics, Georgia Tech, in Feburary 2010. It provided an opportunity for professors, postdocs and graduate students in the extended Atlanta area to meet, exchange ideas, and promote scientific computing research. There were five plenary talks and about sixty participants from Georgia Tech, Emory University, University of Georgia and Georgia State University.

The PI participated and delivered talks at IMACS World congress, computational and applied mathematics and applications in science and engineering (Athans, GA), Konkuk-Hanyang Workshop on Biomedical topics (Konkuk university, Seoul, Korea), KMS-AMS joint meeting in December 2009, SIAM conference in imaging science, International conference on Mathematical Methods for Imaging (Sun Yat-Sen University, Guanzhou, China), and UKC2010 in Seattle, August 2010.

In addition, the PI gave a talk at Emory University, Mathematics and computer science department, SungKyunKwan University (Suwon, Korea), University of Alabama (Tuscaloosa, AL), Georgia Tech, computer science department.

During Fall semester of 2009 and Spring of 2010, some of the PI's collaborators visited Georgia Institute of Technology, discussed various research projects and also gave a research presentations. Some of the visitors includes Justin Wan (University of Waterloo, Canada) , Wei Zhu (University of Alabama) , Chiu-Yen Kao (Ohio State University) , Nicola Guglielmi (University of L'Aquila) , Xiaoming Huo (Georgia Teach, IsyE) , Peter Blomgren (San Diego State University), Haesoon Park(Georgia Tech, CSE), James G. Nagy and Luca Giorda (Emory University), Sookkyung Lim (University of Cincinnati), Jae-Hun Jung (SUNY Buffalo), and Christopher Rorden (Center of Advanced Brain Imaging, Gatech/GSU).

Findings:

One of the major finding is the proposal of automatic multiphase segmentation model. Multiphase segmentation is typically a very unstable process unless a reasonable number is assigned apriori. With Sandberg and Chan, the PI proposed a new model which automatically chooses a reasonable number of phases as it segments the image, and made the multiphase segmentation stable and dependable. This model also has many interesting properties, such as a result showing a balance among different phases, a good detail recovery, a choice of parameter allowing flexibility, and an application to image quantization. By efficiently computing the energy difference, the numerical algorithm was designed to be very fast. (This work published 2010)

Using the techniques of applied analysis, with Barchiesi et al., the PI proposed a model which is an initiating work on capturing a boundary with an infinite perimeter while removing the noise. This work is a good example of how mathematical modeling can open new directions in imaging applications. (published 2010)

Along the lines of finding new methodology, with Ha-Quang and Le, the PI proposed using Reproducing Kernel Hilbert space (RKHS) for image and video colorization. The setting of RKHS and its extensions are widely considered in machine learning, and this is the first work applying RKHS framework to image and video colorization, and the vectorial settings of RKHS are analyzed. The explicit solution is superior compared to any iterative methods, and the flexibility of choosing different kernels allows easy colorization on texture image as well as cartoon images. Colorization results show big improvements in speed and quality. (published 2010)

In addition, with Sandberg and Yip, the PI explored the connections between data mining and image segmentation. The new proposed data mining model is motivated from a variational setting, which shows a flexibility and robustness compared to the classical K-means algorithm. This new model is applied to image scale segmentation which is a new direction in multiphase segmentation. (submitted).

Training and Development:

In Spring 2010, the PI supervised three undergraduate students. Two sophomores, K. Lewis (BME) and T. Siu (ECE), took Math 2699 Research for Credit. They learned the basic mathematical concepts necessary and explored fundamentals of medical imaging. A junior student, E. Trejo (Math), took Math 4080 Senior Project, and worked on classical clustering algorithms. K. Lewis (BME) and E. Trejo (Math) are continuing with their research with the PI.

The PI presented another talk on October 2009, in a research Horizon Seminar (school of Mathematics at Georgia Institute of Technology) to encourage the interests in mathematical research in image processing. This seminar is a weekly seminar geared to first and second-year graduate students. The PI doesn't have any graduate students nor post-doc's at the moment, but actively encouraging research discussion with interested graduate students.

Outreach Activities:

The PI supported the activity of the Center for Education Integrating Science, Mathematics and Computing (CEISMC) at Georgia Tech, by presenting a talk on mathematics and imaging to twenty-five neighboring high school teachers in July 2010.

The PI gave a mathematical talk to about twenty K12 students at KSEA student Mathematica workshop, during UKC2010, Seattle WA. August 2010.

Journal Publications

Sandberg, B. and Kang, S.H. and Chan, T., "Unsupervised Multi-phase Segmentation: A phase balancing model", IEEE Transaction on Image Processing, p. 119, vol. 19, (2010). Published,

Minh Ha-Quang, Sung-Ha Kang, and Triet M. Le, "Image and Video Colorization Using Vector-Valued Reproducing Kernel Hilbert Spaces", Journal of Mathematical Imaging and Vision, p. 49, vol. 37, (2010). Published,

Marco Barchiesi, Sung Ha Kang, Triet Le, Massimiliano Morini, Marcello Ponsiglione, "Infinite perimeter partitions: a variational segmentation model keeping finely oscillating boundaries", SIAM Journal of Multiscale Modeling and Simulation, p. , vol. , (2010). Published,

S. H. Kang, B. Sandberg, and A. Yip, "Multiphase Scale Segmentation and a Regularized K-means", (submitted), p. , vol. , (2010). Submitted,

T. Le, M. Ha-Quang and S. H. Kang, "Reproducing kernel and colorization", Preceedings of the 8th International conference on Sampling Theory and Applications, p. , vol. , (2009). Published,

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

One of the major finding is the proposal of automatic multiphase segmentation model. Multiphase segmentation is typically a very unstable process unless a reasonable number is assigned apriori. With Sandberg and Chan, the PI proposed a new model which automatically chooses a reasonable number of phases as it segments the image, and made the multiphase segmentation stable and dependable. This model also has

many interesting properties, such as a result showing a balance among different phases, a good detail recovery, a choice of parameter allowing flexibility, and an application to image quantization. By efficiently computing the energy difference, the numerical algorithm was designed to be very fast. This model also shows many potential of various applications, one of which is the scale segmentation and data mining connections.

With close collaboration with applied analysts, the PI proposed a new model for image segmentation which captures the oscillatory boundary while denoising the image. This is an initiating work on capturing a boundary with an infinite perimeter while removing the noise. This work is a good example of how mathematical modeling can open new directions in imaging applications. The model shows many interesting properties and has new potentials of interesting image segmentation modeling.

In color image analysis and texture colorization, the new approach using Reproducing Kernel Hilbert space significantly improved the colorization result. The explicit solution is superior compared to any iterative methods, and the flexibility of choosing different kernels allows easy colorization on texture image as well as cartoon images. Colorization results show big improvements in speed and quality, and the authors also studied analytic aspect of using the vectorial setting of Reproducing Kernel Hilbert Spaces.

Extending the idea of automatic multiphase image segmentation, the PI and collaborators proposed a data clustering model which can be applied to scale segmentation. A typical Mumford-Shah-based image segmentation is driven by the intensity of objects in a given image, yet the scale of the object can give added valuable information. Using the scale of objects, the proposed new model can further clearly classify objects in a given image from using only the intensity value. This model also shows a possibility of relating data mining with image segmentation modeling.

Contributions to Other Disciplines:

The scale segmentation model the PI proposed is motivated from multiphase image segmentation, yet solves a data mining problem. The regularized k-means algorithms shows an example that an interesting modeling can make contributions to related fields. This model uses the scale of the object not only the intensity, as a result it can further identify objects via different sizes. This has an important application in medical imaging where it can be meaningful to classify objects via the size not only via the intensity.

One of the project was on image colorization and this is related to real life problems. The term ``colorization'' was introduced by Wilson Markle who first processed the gray scale moon image from the Apollo mission. This term was used to describe the process of adding color to gray scale movies or TV broadcasting program. And this colorization problem is also related to restoration efforts of Italian heritage churches. For example, frescoes paintings by A. Mantegna in an Italian church which was destroyed during World War II. There are photos of the full frescoes available in black and white, while only a few real pieces of frescoes with the original colors are remaining. The objective is to reconstruct the original color of the frescoes (image) from the few remaining real pieces of the original (with color) and the full black and white gray scale photos of the frescoes.

Most of the PI's work is related to real applications such as video and image transmissions, wireless communications, surveillance, and medical imaging such as MRI, cardiac MRI, and ultrasound.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

With abundant developments in video and image transmissions, wireless communications, surveillance, and medical imaging such as MRI, cardiac MRI, Ultra sound, there are high demands for sophisticated image processing methods. The PI's research is using classical studies of calculus of variations and partial differential equations (PDE) based approaches, to find noble applications and new modeling to solve modern imaging problems.
For example, an automatic multiphase segmentation provided a stable way to identify multiple objects, which can be applied in many situation like surveillance or cardiac MRI imaging. The scale segmentation is new techniques to help better classify objects in biology and medical

imaging.

This colorization problem is also related to restoration efforts of (Italian) heritage churches. For example, frescoes paintings by A. Mantegna in an Italian church which was destroyed during World War II. There are photos of the full frescoes available in black and white, while only a few real pieces of frescoes with the original colors are remaining. The objective is to reconstruct the original color of the frescoes (image) from the few remaining real pieces of the original (with color) and the full black and white gray scale photos of the frescoes.

Conference Proceedings

Categories for which nothing is reported:

Organizational Partners

Any Book

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Contributions: To Any Human Resource Development

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