KSIAM 2021 Spring Conference
Korean Society for
Industrial and
Applied Mathematics

June 25–27, 2021
Tops10 Hotel, Gangneung, Korea

Program
제목: 온라인 참가 방법 안내

2021 한국산업응용수학회 볼록학대회는 오프라인, 온라인으로 동시 개최됩니다. ※ 온라인으로 진행되는 발표자료의 녹화 및 화면캡처를 금지합니다.

온라인 세션장 접속 정보

- Zoom 접속 후, '회의 참가'를 클릭하신 후 아래 정보를 입력하시면 각 세션장에 접속 가능합니다.

<table>
<thead>
<tr>
<th>Room</th>
<th>Grand Ballroom</th>
<th>Blue</th>
<th>PDR</th>
<th>Conference</th>
<th>Junior</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>853 2850 0206</td>
<td>852 7003 6594</td>
<td>828 7537 7848</td>
<td>876 6977 0856</td>
<td>871 9098 8460</td>
</tr>
</tbody>
</table>

온라인 참여 안내

■ 주의사항
- 온라인 참여 시, 헤드셋 또는 이어폰을 착용해주세요.
- 안정적인 인터넷 환경에서 참가해주세요.
- 동일 공간에서 복수의 기기로 동일한 온라인 발표장의 접속은 금하지요.

■ 참가자
- 세션장 입장후 참가자의마이크는 음소거됩니다.
- 세션장의 호스트(발언권 지정)는 좌장, 스테프에게 할당됩니다.
- 질문이 있으시면 발표자 채팅창에 남겨주시거나 발표후 질의응답 시간에 손신키 버튼으로 질문의사를 나타낼 경우, 호스트의 진행에 따라 음소거 해제후 진행됩니다.
- 각 온라인 발표장의 주요 안내사항은 채팅창으로 공지됩니다.

세션장 위치

3rd Floor

2nd Floor (Lobby)

Grand Ballroom

Conference

Junior

Elevator

Restaurant
KSIAM 2021 Spring Conference
Gangneung TopsTen Hotel, Gangneung, Korea
June 25-27, 2021

SCHEDULE

- Opening Ceremony: June 25th, 13:50-14:00 [Grand Ballroom]
  - Lee, Chang-Ock (President of KSIAM)

- Plenary Talks
  - Zhang, Byoung-Tak (Computer Science and Engineering, Seoul National University)
    - Steps Toward Human-Level AI
    - June 25th, 14:00-14:50 [Grand Ballroom]
  - Hwang, Ganguk (Department of Mathematical Sciences, KAIST)
    - Bayesian Machine Learning With Gaussian Processes
    - June 26th, 09:30-10:20 [Grand Ballroom]

- KSIAM Young Researcher Paper Award: June 25th, 17:30-18:10 [Grand Ballroom]

- KSIAM Journal Excellent Article Award: June 26th, 13:30-14:10 [Grand Ballroom]

- Poster Session: June 25th, 16:40-17:20

- Special Sessions
  - AI Today in MATLAB
  - Applications of Mathematical Data Science in Industry
  - Biomedical Mathematics
  - Cell Motility
  - CJK-SIAM mini-symposium I: Emerging Mathematics in AI
  - CJK-SIAM mini-symposium II: Mathematical modeling of emerging infectious diseases
  - Mathematics of Geosciences
  - Medical Image Reconstruction and Analysis
  - Numerical Analysis and Machine Learning
  - Optimization and Machine Learning I, II
  - Recent Progress in Digital Dentistry integrating CBCT and Vision

- General Sessions
  - Partial Differential Equations, Applied Probability
  - Biomathematics, Bioinformatics, Biological and Medical Modeling
  - Computer Graphics and Game, IT and Its Industrial Applications, Cryptology
  - Industrial Engineering and Applied Mathematics
  - Inverse Problems, Control and Optimization
  - Applied Analysis
  - Mechanics of Compressible and Incompressible Fluids, Solid Mechanics and Elasticity
  - Numerical Analysis and Scientific Computation

주관: 한국산업응용수학회, 국가수리과학연구소, 부산대학교 빅데이터 기반 금융 수산 제조 혁신
산업육성센터, 성균관대학교 응용대수 및 최적화 연구센터, KAIST 확률 해석 및 응용 연구센터,
서울대학교 산업수학센터
주최: 한국산업응용수학회, BK21 FOUR 포스텍 수리과학 교육연구단
후원: MathWorks, 연세대학교 응용해석 및 계산센터
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<tr>
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<th>Session</th>
<th>Location</th>
<th>Chair</th>
<th>Speaker/Instructor</th>
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<tr>
<td>13:00-13:40</td>
<td>Registration/Opening Ceremony</td>
<td>Grand Ballroom</td>
<td>Chang-Ock Lee</td>
<td>President of KSIAM</td>
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<tr>
<td>14:00-14:20</td>
<td>Plenary Talk 1</td>
<td>Grand Ballroom</td>
<td>Chair: Hyung Ju Hwang</td>
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<tr>
<td>14:30-14:50</td>
<td>Coffee Break</td>
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<tr>
<td>14:50-15:30</td>
<td>Special Session: Optimization and Machine Learning I (Online)</td>
<td>Grand Ballroom</td>
<td>Chair: Donghwan Kim</td>
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<tr>
<td>15:00-15:20</td>
<td>Special Session: Optimization and Machine Learning II (Blue)</td>
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<td>Chair: Jang Won Lee</td>
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<tr>
<td>15:20-15:40</td>
<td>Special Session: Optimization and Machine Learning III (PDR)</td>
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<td>Chair: Kiwan Jeon</td>
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<tr>
<td>15:40-16:00</td>
<td>General Session 1</td>
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<td>Chair: Dongwook Shin</td>
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<tr>
<td>16:00-16:20</td>
<td>General Session 2</td>
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<td>Chair: Ji-Hun Yoon</td>
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<tr>
<td>16:20-16:40</td>
<td>Poster Session 1 (Online)</td>
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<td>Chair: Ji-Hun Yoon</td>
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<tr>
<td>16:40-16:50</td>
<td>Poster Session 2 (Online)</td>
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<td>Chair: Donghwan Kim</td>
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<tr>
<td>16:50-17:00</td>
<td>Poster Session 3 (Online)</td>
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<td>Chair: Sunho Choi</td>
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<tr>
<td>17:00-17:20</td>
<td>Poster Session 4 (Online)</td>
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<td>Chair: Sunmi Lee</td>
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<tr>
<td>17:20-17:40</td>
<td>Poster Session 5 (Online)</td>
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<td>Chair: Do hyun Kim</td>
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</table>

### 15:00-15:20
- **Adamp: Slowing Down the Slowdown for Momentum Optimizers on Scale-Invariant Weight Loss**
  - Speaker: Sanghyuk Chun (NAVER)
  - Focus: The role of Evolving Role Intelligency in Biomedical Applications (MathWorks)

- **Augmentation of orientation trueness of head CBCT radiographs by learning-based skull segmentation improves repeatability and accuracy of craniofacial analysis**
  - Speaker: Sung Min Lee (HDXWILL)
  - Focus: Improved DG method with small edges for Darcy’s flow in fractured porous media (Yonseu Kim (Yonsei National University))

### 15:20-15:40
- **Nonlinear operator theory and fixed-point iterations**
  - Speaker: Ernest K. Ryu (Seoul National University)
  - Focus: AI in Finance Application (Kyu-Hwan Jang (MathWorks))

- **Individual tooth segmentation in 3D dental model using 2D full arch view (Tae Jun Jung (Yonseu University))**
  - Focus: An expanded staggered DG for the heterogeneous diffusion equation (Sanghee Lee (Yonsei University))

### 15:40-16:00
- **Semi-Anchored Multi-Step Gradient Descent Ascent Method for Structured Non-Convex-Nonconcave Composite Minimax Problems**
  - Speaker: Sucheol Lee (KAIST)
  - Focus: Field equipment analytics: Anomaly detection in Power plant case study (Jun-Sang Eom (MathWorks))

- **Fully automated individual tooth-based intra-oral scan and CBCT data**
  - Speaker: Hye Sun Yun (Yonseu University)
  - Focus: Finite element approximation of an incompressible chemically reacting non-Newtonian fluid (Seungchan Ko (University of Hong Kong))

### 16:00-16:20
- **Factor-y/2 Acceleration of Accelerated Gradient Methods**
  - Speaker: Changwoo Park (Seoul National University)
  - Focus: Deploying AI to Embedded and Enterprise Systems (Kyu-Hwan Jang (MathWorks))

- **Recent Progress in Advanced Cephotomy Environment**
  - Speaker: Kiwan Jeon (NIIMS)
  - Focus: Using feature pyramid information for weakly supervised object localization (Bongyeong Koo (Seoul National University))

### 16:20-16:40
- **Stability Analysis of a Three-dimensional Host-parasitoid Model with Logistic Growth Function**
  - Speaker: Jia LLiao (Pusan National University)
  - Focus: Complexity analysis of infestable primal-dual interior point method for semidefinite optimization based on the new class of kernel functions (Jong-Kyu Lee (Pusan National University))

- **Information Maximizing Generative Adversarial Networks for Capacity Estimation Using Importance of Lithium-Ion Batteries**
  - Speaker: Seongyoon Kim (Yonseu University)
  - Focus: Sensitivity and stability analysis of an Ebola Virus disease and GB virus C co-infection (Muhammad Said (Pusan National University))

### 16:40-16:50
- **A study on Convolutional Neural Network for Classification of Brain Tumors**
  - Speaker: Daeeun Kim (Inha university)
  - Focus: Closed-form pricing formula for foreign equity option with credit risk (Donghyun Kim (Pusan National University))

- **Novel methods for effective household object classification using depth images**
  - Speaker: Jungkeong Kif (Seoul National University)
  - Focus: The Pricing of Vulnerable Power Options with Double Mellin Transforms (Mijn Ha, Qi Li (Pusan National University))

### 16:50-17:00
- **Particle Filter and Ensemble Kalman Filter for Stochastic ODE**
  - Speaker: Soyeon Kim (Pusan National University)
  - Focus: CNN-based Prediction of Kneepoint in Capacity Degradation of Li-Ion Batteries (Hangsoo Jung (Yonsei University))

- **Mathematical Modeling and Simulation of Lithium-Ion Batteries**
  - Speaker: Sanghyuk Chun (NAVER)
  - Focus: Efficient immersed boundary projection method for heat transfer problems (Tiantian Xu (Yonsei university))

- **A Bayesian Deep Learning Framework For Uncertainty Quantification of Stochastic Partial Differential Equations**
  - Speaker: Yea Chan Park (Seoul National University)
  - Focus: Particle filtering for spatio-temporal patterns of COVID-19 using dynamic mode decomposition (Sanghee Lee (Yonsei University))

- **Spatial-temporal patterns of COVID-19 using dynamic mode decomposition**
  - Speaker: Minseok Kim (KyuHngHee University)
  - Focus: Personalized sleep-wake patterns aligned with circadian rhythm relieve daytime sleepiness (Seho Park (KAIST))

- **Particle Tracking Using LTRANS**
  - Speaker: DongHeon Seong, Mi Ji Kim (Pusan National University)
  - Focus: The effect of the awareness and treatment on TV’s spread in developing and developed countries (Sajida Parvez (Pusan National University))

- **Blood Flow in Catheterized Artery**
  - Speaker: Javeed Shama (Pusan National University)
  - Focus: The effect of the awareness and treatment on TV’s spread in developing and developed countries (Sajida Parvez (Pusan National University))
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<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Details</th>
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<tbody>
<tr>
<td>17:00-17:05</td>
<td><strong>[Grand Ballroom]</strong></td>
<td>Chair: Ji-Hun Yoon</td>
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<tr>
<td></td>
<td><strong>Poster Session 1 [Online]</strong></td>
<td>Construction of a WENO scheme based on the exponential approximation space enhancing the third-order WENO scheme Kyungrok Lee (Yonsei University)</td>
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<td></td>
<td><strong>Poster Session 2 [Online]</strong></td>
<td>Singular value decomposition of the attenuated conical Radon transform with a fixed central axis and opening angle Gihyeon Jeon (Kyunghpook National University)</td>
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<td></td>
<td><strong>Poster Session 3 [Online]</strong></td>
<td>Applications of the Particle Filter to the Double-Well Potential Model (DWPMM) Azimov Sherkhon and Ugli (Pusan National University)</td>
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<td></td>
<td><strong>Conference</strong></td>
<td>Chair: Sunho Choi</td>
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<td></td>
<td><strong>Poster Session 4 [Online]</strong></td>
<td>4D-Var Method with Lorenz 63 Model Eun Hae Cho (Pusan National University)</td>
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<td>17:05-17:10</td>
<td><strong>[Blue]</strong></td>
<td>Chair: Dongwook Shin</td>
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<td><strong>Distinguishing non-tuberculous mycobacteria lung disease and tuberculosis using deep learning</strong> Yojin Lee (Pusan National University)</td>
<td>Universally valid reduction of multiscale stochastic biochemical systems with simple non-elementary propensities Yun Min Song (KAIST)</td>
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<td><strong>Efficient training of pricing networks using Greeks</strong> Namjum Kim (Chonnam National University)</td>
<td>Efficient training of pricing networks using Greeks Namjum Kim (Chonnam National University)</td>
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<td><strong>Web-Based Diagnostic Performance Comparison of Mobile phone and Computer through CNN in Diagnosing Thyroid Nodule on Ultrasonography</strong> Beomgi So (Yonsei University)</td>
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<td><strong>[Junior]</strong></td>
<td>Chair: Dohyun Kim</td>
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<td><strong>Effect on tumor growth in systems of two different types of tumor-associated neutrophils - A mathematical model</strong> Han Eol Cho (Konkuk University)</td>
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</tr>
<tr>
<td>17:10-17:15</td>
<td><strong>Optimal constant for generalized diagonal update method</strong> Jeong Hoon Ju (Pusan National University)</td>
<td>Data Assimilation: real-time forecasting Hand-Foot-and-Mouth Disease(HFMD) Siun Lee (Pusan National University)</td>
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<td><strong>Development of a mathematical model for predicting accurate heratic clearance of drug</strong> Eun Han Goo (KAIST)</td>
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<td><strong>Benefits of the reward system in text generation</strong> Yedarm Seong (Seoul National University)</td>
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<td><strong>Understanding and Optimal Ensemble Size of Ensemble Kalman Filter via Lorenz Model</strong> GyungMin Lim, Jihyeon Kim (Pusan National University)</td>
<td>Understanding and Optimal Ensemble Size of Ensemble Kalman Filter via Lorenz Model GyungMin Lim, Jihyeon Kim (Pusan National University)</td>
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<tr>
<td>17:15-17:20</td>
<td><strong>A Study on the Effects of Isolation and Contact-Tracing Interventions for COVID-19 in South Korea</strong> Hohyung Ryu (Kyung Hee University)</td>
<td>A Study on the Effects of Isolation and Contact-Tracing Interventions for COVID-19 in South Korea Hohyung Ryu (Kyung Hee University)</td>
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<td><strong>Composition - Aware Image Steganography through Adversarial Self-Generated Supervision</strong> Yuumeng Hu (Pusan National University)</td>
<td>Composition - Aware Image Steganography through Adversarial Self-Generated Supervision Yuumeng Hu (Pusan National University)</td>
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<td><strong>Designing optimizing procedure for task switching to ensure efficiency in the hospital laboratory</strong> Garam Kim (Technische Universität Berlin)</td>
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<td><strong>Data-based inference method reveals the network structure of the circadian clock</strong> Seokjoo Chae (KAIST)</td>
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</tr>
</tbody>
</table>

17:20-17:30 Coffee Break

17:30-17:40 [Grand Ballroom] Delivery of Appreciation Plaques & Ceremony for KSIAM Young Researcher Paper Award Chair: Dosang Joe

17:40-18:10 [Grand Ballroom] Talk for KSIAM Young Researcher Paper Award Chair: Dosang Joe

Spatiotemporal stochastic modeling reveals a hidden compensation mechanism for robust daily rhythms Dae Wook Kim (KAIST)

18:10- Dinner
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<th>Location</th>
<th>Title</th>
<th>Institution/University</th>
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<tbody>
<tr>
<td>09:00-</td>
<td>Registration</td>
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<tr>
<td>09:30-10:20</td>
<td>[Grand Ballroom] Plenary Talk II</td>
<td>Chair: Dosang Joe</td>
<td></td>
<td>Bayesian Machine Learning With Gaussian Processes</td>
<td>Ganguk Hwang (KAIST)</td>
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<tr>
<td>10:20-10:40</td>
<td>Coffee Break</td>
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<td>11:00-11:20</td>
<td>Accelerated Algorithms for Smooth Convex-Concave Minimax Problems with (O(1)/ε²) Rate on Squared Gradient Norm</td>
<td>Chair: Taeho Yoon</td>
<td>[Online] Domains adaptation</td>
<td>Deep learning approaches for generalized multiscale</td>
<td>Minam Moon (Korea Military Academy)</td>
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<td>solving problems using artificial intelligence methods</td>
<td>Yewha Women's University</td>
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<td>[Seoul National University]</td>
<td>with Shape Prior for 3D Low Dose Maxillofacial CBCT Imaging</td>
<td>(KAIST)</td>
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<td>11:40-12:00</td>
<td>Proximity Operator of the Matrix Perspective Function and its Applications</td>
<td>Chair: Jong-Ho Won</td>
<td>[Online] Two-level domain</td>
<td>Development of an algorithm improving label arrangements in</td>
<td>Hee Jun Yang (Kyung Hee University)</td>
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<td>decomposition algorithms for</td>
<td>offset printing</td>
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<td>physics-informed neural networks</td>
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<td>12:00-13:30</td>
<td>Lunch</td>
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<tr>
<td>13:30-14:40</td>
<td>[Grand Ballroom] Ceremony for KSIAM Journal Excellent Article Award</td>
<td>Chair: Jin Yeon Cho</td>
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<tr>
<td>13:40-14:10</td>
<td>[Grand Ballroom] Talk for KSIAM Journal Excellent Article Award</td>
<td>Chair: Jin Yeon Cho</td>
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<td>14:10-14:30</td>
<td>Coffee Break</td>
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<td>14:30-14:50</td>
<td>[Grand Ballroom] WGAN with an infinitely wide generator has no spurious stationary points</td>
<td>Chair: Yasuhiro Igarashi</td>
<td>[Blue]</td>
<td>PK/PD modeling and its utilization in drug development and</td>
<td>Kyoung Kim (Chungnam National University)</td>
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<td>real-world data prediction</td>
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Note: The [Online] sessions indicate virtual presentations or discussions.
### KSIAM 2021 Spring Conference

#### June 26 (SAT) Session

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<tr>
<td></td>
<td>Chair: Chang Hyeong Lee</td>
<td>Chair: Wanhoo Lee</td>
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<td>Chair: Sung-Ik Sohn</td>
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<tr>
<td>16:10-16:30</td>
<td>Forecasting the spread of COVID-19 according to the effect of interventions in Republic of Korea</td>
<td>How do flagellated bacteria swim?</td>
<td>SWE conservational error caused by geometric approximation error on the spherical earth</td>
<td>Quasi-interpolation of multivariate functions on sparse grids</td>
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<td>Hyeong Lee (NIMS)</td>
<td>Sookkyung Lim (University of Cincinnati)</td>
<td>Sehun Chun (Yonsei University)</td>
<td>Byeongseon Jeong (Ewha Womans University)</td>
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<td>16:30-16:50</td>
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Plenary Talks

Byoung-Tak Zhang (Seoul National University)
Hwang, Ganguk (KAIST)
Steps Toward Human-Level AI

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ABSTRACT

Machine learning has revolutionized the way we develop the intelligent systems. Instead of human programming, the machine learning approach endows the machine with intelligence by automatic learning from data. Deep learning is a pinnacle of the current machine learning approach. However, most deep learning involves specific, narrow intelligence which is usually still far from human-level intelligence. In this talk I consider why we need to go further toward human-level artificial general intelligence and what steps we can proceed to study and develop human-level AI.
BAYESIAN MACHINE LEARNING
WITH GAUSSIAN PROCESSES

GANGUK HWANG

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ABSTRACT

Gaussian Processes have been widely used in a nonparametric Bayesian machine learning approach that places a flexible prior distribution over the space of functions and returns a predictive distribution through a combination of the prior and the data. The benefits of the use of Gaussian process in inference, learning, and prediction come from its analytical tractability and practical advantages.

In this talk, we first introduce the basics of Gaussian process and then see how Gaussian processes are used in machine learning problems such as regression and classification. We also explain scalable Gaussian processes and sparse approximation to deal with big data. Finally, we provide some recent results on machine learning problems with Gaussian processes.
KSIAM 2021 Spring Conference
Korean Society for
Industrial and
Applied Mathematics

June 25–27, 2021
Tops10 Hotel,
Gangneung, Korea

Program

KSIAM Awards

- Dae Wook Kim (KAIST)
- Kyeol Yune (Seoul National University)
Spatiotemporal stochastic modeling reveals a hidden compensation mechanism for robust daily rhythms

Stephen Beesley1, a, Dae Wook Kim2, a, Matthew D’Alessandro1, Yuanhu Jin1, Kwangjun Lee1, Hyunjeong Joo1,3, Yang Young3, Robert J. Tomko Jr1, John Faulkner4, Joshua Gamsby4, Jae Kyoung Kim2 and Choogon Lee1

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a) S.B. and D.W.K. contributed equally to this work

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ABSTRACT

Circadian (daily) physiological events, such as sleep and cell division, are essential for survival of humans. Their robust timekeeping capabilities are controlled by an endogenous pacemaker, the circadian clock. Its key molecular oscillatory mechanism has been identified by experimental work over the past decades whose significance was appreciated and thus the 2017 Nobel Prize in Physiology or Medicine was awarded to the three pioneer researchers. However, our understanding of this mechanism remains far from complete. How are the robust rhythms generated within a single cell with a heterogeneous cytoplasmic environment, which directly influences the manifestation of these rhythms? To address this question, which is challenging because it requires to consider time, space and stochasticity together, we have developed a spatiotemporal stochastic mathematical model of the system for the first time. By analyzing the model, we identified a potential mechanism for how the clock generates the robust rhythms over a wide range of cytoplasmic congestion levels: spatially coordinated collective behaviors of clock molecules. This provides a clear mechanistic insight into why sleep disorders arise under clinical conditions, such as Alzheimer’s disease, obesity and aging, where the cytoplasmic environment can be severely disrupted. Surprisingly, these model predictions have been confirmed experimentally. This study sheds light on novel molecular dynamics for robust cellular rhythms and provides theoretical frameworks which can be broadly applied in cell physiology.
DESIGN OF LEAST-SQUARE SWITCHING FUNCTION
FOR ACCURATE AND EFFICIENT GRADIENT
ESTIMATION ON UNSTRUCTURED GRID

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2) Agency for Defense Development, Korea
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ABSTRACT

An accurate and efficient gradient estimation method on unstructured grid is presented by proposing a switching process between two Least-Square methods. Diverse test cases show that the gradient estimation by Least-Square methods exhibit better characteristics compared to Green-Gauss approach. Based on the investigation, switching between the two Least-Square methods, whose merit complements each other, is pursued. The condition number of the Least-Square matrix is adopted as the switching criterion, because it shows clear correlation with the gradient error, and it can be easily calculated from the geometric information of the grid. To illustrate switching process on general grid, condition number is analyzed using stencil vectors and trigonometric relations. Then, the threshold of switching criterion is established. Finally, the capability of Switching Weighted Least-Square method is demonstrated through various two- and three-dimensional applications.
Special Session

- Optimization and Machine Learning I
- AI Today in MATLAB
- Recent Progress in Digital Dentistry integrating CBCT and Vision
- Optimization and Machine Learning II
- Medical Image Reconstruction and Analysis
- Numerical Analysis and Machine Learning
- Applications of Mathematical Data Science in Industry
- CJK-SIAM mini-symposium I: Emerging Mathematics in AI
- Biomedical Mathematics
- CJK-SIAM mini-symposium II: Mathematical modeling of emerging infectious diseases
- Cell Motility
- Mathematics of Geosciences
Special Session

Optimization and Machine Learning I

- Sanghyuk Chun (NAVER)
- Ernest K. Ryu (Seoul National University)
- Sucheol Lee (KAIST)
- Chanwoo Park (Seoul National University)
ADAMP: SLOWING DOWN THE SLOWDOWN FOR MOMENTUM OPTIMIZERS ON SCALE-IN Variant WEIGHTS

Byeongho Heo, Sanghyuk Chun, Seong Joon Oh, Dongyoon Han, Sangdoo Yun, Gyuwan Kim, Youngjung Uh, and Jung-Woo Ha

1) Naver AI Lab
2) Applied Information Engineering, Yonsei University (Works done at Naver AI Lab)

Byeongho Heo and Sanghyuk Chun contribute equally.

ABSTRACT
Normalization techniques, such as batch normalization (BN), have become standard tools for training deep neural network models. Originally proposed to reduce the internal covariate shift [2], normalization methods have proven to encourage several desirable properties in deep neural networks, such as better generalization and the scale invariance [3]. Prior studies have observed that the normalization-induced scale invariance of weights stabilizes the convergence through automatic step size reduction over time, stabilizing the overall training procedure. However, it is often overlooked that the additional introduction of momentum in GD optimizers results in a far more rapid reduction in effective step sizes for scale-invariant weights, a phenomenon that has not yet been studied and may have caused unwanted side effects in the current practice. This is a crucial issue because arguably the vast majority of modern deep neural networks consist of (1) momentum-based GD (e.g. SGD or Adam) and (2) scale-invariant parameters (e.g. more than 90% of the weights in ResNet are scale-invariant due to BN). In this paper, we verify that the widely-adopted combination of the two ingredients lead to the premature decay of effective step sizes and sub-optimal model performances. We propose a simple and effective remedy, SGDP and AdamP: get rid of the radial component, or the norm-increasing direction, at each optimizer step. Because of the scale invariance, this modification only alters the effective step sizes without changing the effective update directions, thus enjoying the original convergence properties of GD optimizers. Given the ubiquity of momentum GD and scale invariance in machine learning, we have evaluated our methods against the baselines on 13 benchmarks. They range from vision tasks like classification (e.g. ImageNet), retrieval (e.g. CUB and SOP), and detection (e.g. COCO) to language modelling (e.g. WikiText) and audio classification (e.g. DCASE) tasks. We verify that our solution brings about uniform gains in performances in those benchmarks. The full study is presented at International Conference on Learning Representations (ICLR) [1].

PRIMARY HEADING
Normalization techniques, such as batch normalization (BN) [2], have become standard tools for training deep neural network models. Originally proposed to reduce the internal covariate shift [2], normalization methods have proven to encourage several desirable properties in deep neural networks, such as better generalization and the scale invariance [3]. Prior studies have observed that the normalization-induced scale invariance of weights stabilizes the convergence...
for the neural network training [3,4]. We provide a sketch of the argument here. Given weights $w$ and an input $x$, we observe that the normalization makes the weights become scale-invariant:

$$\text{Norm}(w^\top x) = \text{Norm}(cw^\top x) \quad \forall c > 0.$$  

(1)

The resulting equivalence relation among the weights lets us consider the weights only in terms of their $\ell_2$-normalized vectors $\tilde{w} := \frac{w}{\|w\|_2}$ on the sphere $S^{d-1} = \{v \in \mathbb{R}^d : \|v\|_2 = 1\}$. We refer to $S^{d-1}$ as the effective space, as opposed to the nominal space $\mathbb{R}^d$ where the actual optimization algorithms operate. The mismatch between these spaces results in the discrepancy between the gradient descent steps on $\mathbb{R}^d$ and their effective steps on $S^{d-1}$. Specifically, for the gradient descent updates, the effective step sizes $\|\Delta \tilde{w}_{t+1}\|_2 := \|\tilde{w}_{t+1} - \tilde{w}_t\|_2$ are the scaled versions of the nominal step sizes $\|\Delta w_{t+1}\|_2 := \|w_{t+1} - w_t\|_2$ by the factor $\frac{1}{\|w_t\|_2}$ [3]. Since $\|w_t\|_2$ increases during training [4], the effective step sizes $\|\Delta \tilde{w}_t\|_2$ decrease as the optimization progresses. The automatic decrease in step sizes stabilizes the convergence of gradient descent algorithms applied on models with normalization layers: even if the nominal learning rate is set to a constant, the theoretically optimal convergence rate is guaranteed [4].

In this work, we show that the widely used momentum-based gradient descent optimizers decreases the effective step size $\Delta \tilde{w}_t$ even more rapidly than the momentum-less counterparts considered in [4]. This leads to a slower convergence for $\tilde{w}_t$ and potentially sub-optimal model performances. This phenomenon is not confined to the toy setup, for example, 95.5% and 91.8% of the parameters of the widely-used ResNet18 and ResNet50 [5] are scale-invariant due to BN.

We propose a simple solution to slow down the decay of effective step sizes while maintaining the step directions of the original optimizer in the effective space. At each iteration of a momentum-based gradient descent optimizer, we propose to project out the radial component (i.e. component parallel to $w$) from the update, thereby reducing the increase in the weight norm over time. Because of the scale invariance, the procedure does not alter the update direction in the effective space; it only changes the effective step sizes. We apply this technique on SGD and Adam [6] (SGDP and AdamP, respectively) and verify the resulting performance boosts over a diverse set of practical machine learning tasks.

REFERENCES

NONLINEAR OPERATOR THEORY AND FIXED-POINT ITERATIONS

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ABSTRACT

While the study of linear operators has a long and extensive history, nonlinear operators have received significantly less attention. In this talk, we discuss the one-to-one correspondence between nonexpansive operators and nonlinear monotone operators. This correspondence relates the theory of nonlinear operators to the wide range of algorithms in applied mathematics and machine learning expressed as nonexpansive fixed-point iterations. We then discuss recent advances in the tools for analyzing nonlinear operators and their applications in machine learning. This talk is based on the upcoming book [1].

REFERENCES

SEMI-ANCHORED MULTI-STEP GRADIENT DESCENT ASCENT METHOD FOR STRUCTURED NONCONVEX-NONCONCAVE COMPOSITE MINIMAX PROBLEMS

Sucheol Lee$^1$ and Donghwan Kim$^1$

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ABSTRACT
Minimax problems, such as generative adversarial network, adversarial training, and fair training, are often solved by a multi-step gradient descent ascent (MGDA) method. However, its convergence guarantee is limited. In this paper, inspired by the primal-dual hybrid gradient method, we propose a new semi-anchoring (SA) technique for the MGDA method. This makes the MGDA method find a stationary point of structured nonconvex-nonconcave composite minimax problems. The resulting method, named SA-MGDA, is built upon a Bregman proximal point method. We show that the worst-case rate of the SA-MGDA method, in terms of the Bregman distance between two successive iterates, is $O(1/k)$, where $k$ denotes the number of iterations. We further develop its backtracking line-search version, and its non-Euclidean version for smooth adaptable functions. Numerical experiment of fair classification training is provided.
Factor-$\sqrt{2}$ Acceleration of Accelerated Gradient Methods

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ABSTRACT

The optimized gradient method (OGM) provides a factor-$\sqrt{2}$ speedup upon Nesterov’s celebrated accelerated gradient method in the convex (but non-strongly convex) setup. However, this improved acceleration mechanism has not been well understood; prior analyses of OGM relied on a computer-assisted proof methodology, so the proofs were opaque for humans despite being verifiable and correct. In this work, we present a new analysis of OGM based on a Lyapunov function and linear coupling. These analyses are developed and presented without the assistance of computers and are understandable by humans. Furthermore, we generalize OGM’s acceleration mechanism and obtain a factor-$\sqrt{2}$ speedup in other setups: acceleration with a simpler rational stepsize, the strongly convex setup, and the mirror descent setup.
KSIAM 2021 Spring Conference
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Program

Special Session

AI Today in MATLAB

- Jun-Sang Eom (MathWorks)
- Kyu-Hwan Jang (MathWorks)
- Jun-Sang Eom (MathWorks)
- Kyu-Hwan Jang (MathWorks)
The Evolving Role of Artificial Intelligence in Biomedical Applications

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ABSTRACT

Artificial Intelligence, or AI, is powering a massive shift in the roles that computers play in our personal and professional lives. Techniques like Machine and Deep Learning are quickly becoming mainstream technologies that can analyze large volumes of data and potentially unlock insights especially in biomedical applications. These techniques have the potential to help improve patient care and clinical outcomes. Many technical leaders within engineering organizations are looking to strengthen their competitive advantage using these capabilities. The big question is, are you in a position to fulfill that expectation, to transform your research, your products and your business using AI, or do you think AI to be yet another buzz word that is going around.

In this session, we will take you through some real-world examples shared by our customers which can help you understand and figure out if AI is a good fit for your work, and if so, how you can use MATLAB & Simulink to adopt AI and gain competitive advantage. We will introduce some examples of how AI fits in to your existing workflow and how you can potentially gain from this new technology regardless of your background or expertise in this field.
AI in Finance Application

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ABSTRACT

Artificial intelligence (AI) is used in the financial services industry to automate, enhance, and optimize processes; make more accurate predictions; and autonomously learn from experience.

AI in finance includes machine learning, deep learning, reinforcement learning, natural language processing, graph algorithms, evolutionary learning, and other techniques. You can apply these techniques using MATLAB®.

Deep learning, a subset of machine learning, utilizes neural networks and is applied to machine learning problems simultaneously perform feature extraction and prediction within the neural network architecture. This approach eliminates the need to perform feature extraction prior to developing a predictive model. Moreover, deep learning requires a substantial historical training data set to build a robust and accurate predictive model. For example, nonlinearities in oil price distribution such as volatility are captured by neural network models.

Reinforcement learning helps alleviate this challenge by generating the needed data. It does this through repeated simulations (via trial and error) with a reward structure for good outcomes. Its aim is to learn a “behavior” as opposed to fitting a model with the highest possible accuracy. The goal of reinforcement learning is to train a model to take actions or make decisions in order to maximize the cumulative reward. One financial application is to train an agent to hedge a European call option contract and save on transaction costs.

In this session, you will see practitioners of AI application in finance.

Highlights

- Classifying Trading Signal using Machine Learning and Deep Learning
- What is Reinforcement Learning?
- Case Study: Development of a self-learning financial trading agent
Field equipment analytics: Anomaly detection in Power plant case study

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ABSTRACT

The detection of unexpected loose parts in the primary coolant system in a power plant remains an extremely important issue. It is essential to develop a methodology for the localization and mass estimation of loose parts owing to the high prediction error of conventional methods. An effective approach is presented for the localization and mass estimation of a loose part using machine-learning and deep-learning algorithms. First, a methodology was developed to estimate both the impact location and the mass of a loose part at the same times in a real structure in which geometric changes exist. Second, an impact database was constructed through a series of impact finite-element analyses (FEAs). Then, impact parameter prediction modes were generated for localization and mass estimation of a simulated metallic loose part using machine-learning algorithms (artificial neural network, Gaussian process, and support vector machine) and a deep-learning algorithm (convolutional neural network). The usefulness of the methodology was validated through blind tests, and the noise effect of the training data was also investigated. The high performance obtained in this study shows that the proposed methodology using an FEA-based database and deep learning is useful for localization and mass estimation of loose parts on site.

REFERENCES

2. Seong-In Moon et al “Plate bending wave propagation behavior under metal sphere impact loading”
Deploying AI to Embedded and Enterprise Systems

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ABSTRACT

Deploying AI raises challenges beyond those associated with developing a performant AI model, including:

- Meeting hardware constraints of the deployment environment, such as limited memory and power consumption
- Monitoring and maintaining model performance over their lifetime

Learn about expanded capabilities to address the above challenges for both compiler-based and embedded deployment using code generation:

1. Quantization: Fixed-point conversion for machine learning models and quantization for deep neural networks allow them to fit on hardware with limited memory and power.
2. Incremental learning and model updates: Code generation that separates parameters from prediction code and incremental learning make it possible to improve models continuously. DevOps provides a framework for managing and governing AI models across their life cycle.
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Program

Special Session

Recent Progress in Digital Dentistry
integrating CBCT and Vision

- Sung Min Lee (HDXWILL)
- Tae Jun Jang (Yonsei University)
- Hye Sun Yun (Yonsei University)
- Kiwan Jeon (NIMS)
Augmentation of orientation trueness of head CBCT radiographs by learning-based skull segmentation improves repeatability and accuracy of craniofacial analysis

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ABSTRACT

Accurate and robust cephalometry for 3D CBCT images is an important task for the diagnosis, surgical planning, growth analysis, and treatment evaluation. For accurate cephalometry, a reference plane for determining the head rotation of the CBCT image is required. However, the conventional landmark-based reference plane determination method has a large error between investigators and within the investigator, resulting in poor cephalometry reproducibility. We address this issue by proposing a method consisting of three stages. 1) skull segmentation using a learning-based method in CBCT images, 2) detecting a region that does not depend on head rotation from the segmented data, 3) determining head rotation by applying PCA (Principal Components Analysis) in the region.
Individual tooth segmentation in 3D dental model using 2D full arch view

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ABSTRACT

Accurate individual tooth segmentation of digital dental model is essential in computer-aided-design (CAD) system for orthodontics and prosthesis. This study proposes a fully automated method for individual tooth segmentation in dental model. It consists of multi-steps based on deep learning to address computational complexity associated by high-dimensional data. First, a two-dimensional (2D) shadowed image and depth image showing the full arch, are automatically generated from the dental model. These low-dimensional images are used to predict bounding boxes of teeth in the dental model. The obtained bounding boxes provide 3D regions of interest (ROIs) for individual teeth. Finally, individual tooth segmentation is performed by a deep learning method for point cloud using the 3D ROIs. Experiment results showed that the proposed method achieves a Dice similarity score 95.96% for 3D individual tooth segmentation.
Fully automated individual tooth-based registration of intra-oral scan and CBCT data
Hye Sun YUN

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ABSTRACT

The paper presents a fully automated registration method of integrating intra-oral scan (IOS) and dental cone-beam computerized tomography (CBCT) images. Low dose dental CBCT alone may not be able to provide precise details of the tooth surface due to various CT artifacts, including metal-induced artifacts. On the other hand, IOS is quite accurate for short partial tooth arches, but not for long full dental arches due to the cumulative error that occurs during stitching process of local scans. This registration is intended not only to compensate the inaccuracy of CBCT-derived tooth surfaces with IOS, but also to correct cumulative stitching errors of IOS across the entire tooth arch. This automated method removes cumbersome and time-consuming procedure of manual matching via initial clicking of reference points on tooth surface.

The proposed fully automated registration method consists of four steps. The first step is to automatically segment individual teeth in both CBCT and IOS. The second step is to coarsely match the segmented tooth data obtained in Step 1. In the third step, an iterative closest point method is used to get a fine matching. The final step corrects the stitching error of IOS using partially overlapping area between IOS and CBCT-derived tooth surfaces. The proposed model can be used for digital dentistry for occlusion analysis and digital surgical guide to reduce orthodontic mini-screw failure by minimizing root contact. Experiments show that the proposed method can successfully coarse matching without using manual clicking.
Recent Progress in Advanced Cephalometry Environment

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ABSTRACT

Advances in computed tomography (CT) technology have led to the innovations of the diagnosis in numerous medical fields. In particular, the utilization of CT images is increasing in the field of dental treatment and orthognathic surgery.

Digital dentistry, digitizing the entire dental treatment process from the traditional analog one, is based on CT images and various vision-based scanner data. With competitive domestic CT companies in the global market, digital dentistry accompanying with cutting-edge deep learning techniques is being promoted as a national R&D strategy.

Digital dentistry requires a framework based on software that can manipulate and visualize the data from varied sources. To achieve our research purpose for digital dentistry, we are developing some image processing softwares and are building a software environment that can integrate them.

In this talk, we present the Advanced Cephalometry Environment (ACE), a software integration environment under development currently, and discuss the future development direction.
KSIAM 2021 Spring Conference
Korean Society for Industrial and Applied Mathematics

June 25–27, 2021
Tops10 Hotel, Gangneung, Korea

Program

Special Session

Optimization and Machine Learning II

- Se-Young Yun (KAIST)
- TaeHo Yoon (Seoul National University)
- Jongmin Lee (Seoul National University)
- Joong-Ho Won (Seoul National University)
Meta-Learning and Representation Change

Jaehoon Oh¹, Hyungjun Yoo¹, ChangHwan Kim¹ and Se-Young Yun²

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ABSTRACT

Model Agnostic Meta-Learning (MAML) is one of the most representative of gradient-based meta-learning algorithms. MAML learns new tasks with a few data samples using inner updates from a meta-initialization point and learns the meta-initialization parameters with outer updates. It has recently been hypothesized that representation reuse, which makes little change in efficient representations, is the dominant factor in the performance of the meta-initialized model through MAML in contrast to representation change, which causes a significant change in representations. In this study, we investigate the necessity of representation change for the ultimate goal of few-shot learning, which is solving domain-agnostic tasks. To this aim, we propose a novel meta-learning algorithm, called BOIL (Body Only update in Inner Loop), which updates only the body (extractor) of the model and freezes the head (classifier) during inner loop updates. BOIL leverages representation change rather than representation reuse. This is because feature vectors (representations) have to move quickly to their corresponding frozen head vectors. We visualize this property using cosine similarity, CKA, and empirical results without the head. BOIL empirically shows significant performance improvement over MAML, particularly on cross-domain tasks. The results imply that representation change in gradient-based meta-learning approaches is a critical component. This paper was presented at ICLR 2021.

MOTIVATION AND CONTRIBUTION

Meta-learning, also known as “learning to learn,” is a methodology that imitates human intelligence that can adapt quickly with even a small amount of previously unseen data through the use of previous learning experiences. To this aim, meta-learning with deep neural networks has mainly been studied using metric- and gradient-based approaches. Metric-based meta-learning [4, 12, 14, 17] compares the distance between feature embeddings using models as a mapping function of data into an embedding space, whereas gradient-based meta-learning [2, 7, 10] quickly learns the parameters to be optimized when the models encounter new tasks.

Model-agnostic meta-learning (MAML) [2] is the most representative gradient-based meta-learning algorithm. MAML algorithm consists of two optimization loops: an inner loop and an outer loop. The inner loop learns task-specific knowledge, and the outer loop finds a universally good meta-initialized parameter allowing the inner loop to quickly learn any task from the initial point with only a few examples. This algorithm has been highly influential in the field of meta-learning, and numerous follow-up studies have been conducted [3, 6, 8, 11, 13, 15, 16, 18, 19].
Figure 1. **Difference in task-specific (inner) updates between MAML/ANIL and BOIL.**

In the figure, the lines represent the decision boundaries defined by the head (classifier) of the network. Different shapes and colors mean different classes. (a) MAML mainly updates the head with a negligible change in body (extractor); hence, representations on the feature space are almost identical. ANIL does not change in the body during inner updates, and they are therefore identical. However, (b) BOIL updates only the body without changing the head during inner updates; hence, representations on the feature space change significantly with the fixed decision boundaries. We visualize the representations from various data sets using UMAP (Uniform Manifold Approximation and Projection for dimension reduction) [5].

Very recent studies [1, 9] have attributed the success of MAML to high-quality features before the inner updates from the meta-initialized parameters. For instance, [9] claimed that MAML learns new tasks by updating the head (the last fully connected layer) with almost the same features (the output of the penultimate layer) from the meta-initialized network. In this paper, we categorize the learning patterns as follows: A small change in the representations during task learning is named **representation reuse**, whereas a large change is named **representation change**.\(^1\) Thus, **representation reuse** was the common belief of MAML.

Herein, we pose an intriguing question: Is **representation reuse** sufficient for meta-learning? We believe that the key to successful meta-learning is closer to **representation change** than to **representation reuse**. More importantly, **representation change** is crucial for cross-domain adaptation, which is considered the ultimate goal of meta-learning. By contrast, the MAML accomplished with **representation reuse** might be poorly trained for cross-domain adaptation since the success of **representation reuse** might rely heavily on the similarity between the source and the target domains.

To answer this question, we propose a novel meta-learning algorithm that leverages **representation change**. Our contributions can be summarized as follows:

- We propose a simple but effective meta-learning algorithm that learns the **Body (extractor) of the model Only in the Inner Loop** (BOIL). We empirically show that BOIL improves the performance over most of benchmark data sets and that this improvement is particularly noticeable in fine-grained data sets or cross-domain adaptation.
- We demonstrate that the BOIL algorithm enjoys **representation layer reuse** on the low-/mid-level body and **representation layer change** on the high-level body using the cosine similarity and the Centered Kernel Alignment (CKA). We visualize the features between before and after an adaptation, and empirically analyze the effectiveness of the body of BOIL through an ablation study on eliminating the head.
- For ResNet architectures, we propose a disconnection trick that removes the back-propagation path of the last skip connection. The disconnection trick strengthens **representation layer change** on the high-level body.

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\(^1\) In our paper, **representation reuse** and **representation change** correspond to **feature reuse** and **rapid learning** in [9], respectively. To prevent confusion from terminology, we re-express the terms.
REFERENCES


Accelerated Algorithms for Smooth Convex-Concave Minimax Problems with $\mathcal{O}(1/k^2)$ Rate on Squared Gradient Norm

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ABSTRACT

In this work, we study the computational complexity of reducing the squared gradient magnitude for smooth minimax optimization problems. First, we present algorithms with accelerated $\mathcal{O}(1/k^2)$ last-iterate rates, faster than the existing $\mathcal{O}(1/k)$ or slower rates for extragradient, Popov, and gradient descent with anchoring. The acceleration mechanism combines extragradient steps with anchoring and is distinct from Nesterov’s acceleration. We then establish optimality of the $\mathcal{O}(1/k^2)$ rate through a matching lower bound.
A Geometric Structure of Acceleration and Its Role in Making Gradients Small Fast

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ABSTRACT

The many accelerated first-order methods since Nesterov’s seminal 1983 work have been presented without a common underlying structure. In this work, we identify a geometric structure satisfied by a wide range of first-order accelerated methods. Using this geometric insight, we present several novel generalizations of accelerated methods. Most interesting among them is a method that can reduce the squared gradient norm with $O(1/K^4)$ rate in the prox-grad setup, faster than the $O(1/K^3)$ rates of Nesterov’s FGM or Kim and Fessler’s FPGM-m.
Proximity Operator of the Matrix Perspective Function and its Applications

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ABSTRACT

We show that the matrix perspective function, which is jointly convex in the Cartesian product of a standard Euclidean vector space and a conformal space of symmetric matrices, has a proximity operator in an almost closed form. The only implicit part is to solve a semismooth, univariate root finding problem. We uncover the connection between our problem of study and the matrix nearness problem. Through this connection, we propose a quadratically convergent Newton algorithm for the root finding problem. Experiments verify that the evaluation of the proximity operator requires at most 8 Newton steps, taking less than 5s for 2000 by 2000 matrices on a standard laptop. Using this routine as a building block, we demonstrate the usefulness of the studied proximity operator in constrained maximum likelihood estimation of Gaussian mean and covariance, pseudolikelihood-based graphical model selection, and a matrix variant of the scaled lasso problem.

DISCLAIMER

This work was first presented in the Neural Information Processing Systems 2020 Conference (NeurIPS 2020).
KSIAM 2021 Spring Conference
Korean Society for Industrial and Applied Mathematics

June 25–27, 2021
Tops10 Hotel,
Gangneung, Korea

Program

Special Session

Medical Image Reconstruction and Analysis

Kyungsang Kim (Massachusetts General Hospital and Harvard Medical School)
Young Jin Jeong (Dong-A University Hospital)
Chang Min Hyun (Yonsei University)
Hyoung Suk Park (NIMS)
Domain adaptation few-shot learning for PET image denoising

Kyungsang Kim and Quanzheng Li

Department of Radiology, Massachusetts General Hospital and Harvard Medical School
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ABSTRACT

Deep learning has been successfully used for PET image enhancement [1-3]. However, because there are various target regions, doses, and radiotracers, it is almost impossible to train all kinds of deep learning models with sufficient data. Domain adaptation has developed to improve the performance of the new task model and to achieve the generalization. In this paper, we propose a novel domain adaptation few-shot learning method for PET image denoising, where the feature maps from the trained model are directly utilized without source data for computing efficiency. The distributions of feature maps of two domains are used in the feature loss using the KL divergence. The optimization reduces both the feature loss and root mean square error (RMSE) loss. We demonstrate that the proposed method can improve the PET image quantitatively and qualitatively in the target domain with small training data, which demonstrates the feasibility of the generalization for clinical use.

INTRODUCTION

Domain adaptation (DA) has been increasingly investigated to improve the performance for new tasks (target domain, TD) by utilizing the existing data (source domain, SD), where two domains all contain a common feature space but different distribution [4]. Usually, the target domain does not have sufficient data, which is exactly a few-shot learning problem. In this work, we are interested in solving two issues: (1) DA training is computationally inefficient due to a large number of source datasets, and (2) transfer learning cannot change the network structures when the source data is not used. To address these issues, we propose a novel domain adaptation few-shot learning method for PET image denoising. For the computing efficiency, we directly utilize the trained SD model without source data, where the feature maps of the SD model are extracted to be utilized for the training of the DA model. The SD feature map represents the feature map of the trained SD model using target images. Distributions of feature maps for SD and DA are compared by feature loss using the Kullback–Leibler (KL) divergence, which computes the similarity of one distribution to another. Here, the feature loss is designed only for the decoder layers because we want the DA model to learn the distribution of denoised features. By using the distributions of feature maps, we can build more flexible encoder networks. The optimization minimizes both the feature loss and root mean square error (RMSE) loss.

FORMULATION

We firstly train the SD model with sufficient source domain data by minimizing the standard RMSE loss given by,

$$L_s(f_s; X_s, Y_s) = \sum_{i=1}^{N_s} \sqrt{\| f_s(x_s^i) - y_s^i \|_2^2},$$

where $f_s$ is the SD model. $X_s$ and $Y_s$ denote input (noisy) and label (ground truth) images in source domain, respectively. $N_s$ is the number of SD samples.
In our evaluation, we compared RMSE and bias of images using SD, TD, and DA models. The TD model with sufficient 20 patients was used as the lower bound of the performances. The proposed method with small training sets of only 3 patients achieved similar performances compared to the lower bound.

**RESULTS**

Table 1. Comparison of RMSE/BIAS

<table>
<thead>
<tr>
<th></th>
<th>RMSE</th>
<th>BIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noisy</td>
<td>0.0077</td>
<td>0.024</td>
</tr>
<tr>
<td>SD</td>
<td>0.025</td>
<td>0.0088</td>
</tr>
<tr>
<td>TD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.022</td>
<td>0.0078</td>
</tr>
<tr>
<td>6</td>
<td>0.024</td>
<td>0.0086</td>
</tr>
<tr>
<td>3</td>
<td>0.029</td>
<td>0.0108</td>
</tr>
<tr>
<td>DA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.023</td>
<td>0.0080</td>
</tr>
<tr>
<td>3</td>
<td>0.023</td>
<td>0.0083</td>
</tr>
</tbody>
</table>

In our evaluation, we compared RMSE and bias of images using SD, TD, and DA models. The TD model with sufficient 20 patients was used as the lower bound of the performances. The proposed method with small training sets of only 3 patients achieved similar performances compared to the lower bound.

CONCLUSION

In conclusion, we proposed the domain adaptation few-shot learning method for PET image denoising. The proposed method improved the PET image quantitatively and qualitatively in the target domain with small training data and showed the feasibility of the generalization with computing efficiency for clinical use.

REFERENCES

PET 영상을 대상으로 인공지능기법을 이용한 문제해결 경험

Experience in solving problems using artificial intelligence methods on PET images (with NIMS)

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요약

전통적으로 의료 영상은 의사들이 육안적 소견을 바탕으로 정상과 비정상으로 분류하였으며, 주관적이거나 경험에 영향을 받는 육안 판독의 단점을 보안하고자 standardized uptake value ratio (SUVR) 등의 정량 평가 결과를 함께 이용하고 있다. 좀 더 객관적이고 정확한 판단을 위해 비교적 최근에는 SPM, PMOD, FreeSurfer 등의 의료영상분석용 전문 프로그램을 이용해서 정성적, 정량적 분석을 동시에 수행하고 있다.

X-ray 사진과 같은 초기 형태의 영상검사는 1-3 장의 사진이 나오는데 반해 최근에는 한가지 검사에서 최대 3 천여장의 사진이 제공되며, 이러한 방면의 양의 사진이 한 병원에서 매일 수백명의 사람에게서 촬아져 나오키 때문에 사람이 처리할 수 있는 양과 속도에 한계가 온 수밖에 없었고, 좀 더 정확하면서도 빠른 영상 분석법이 필요하게 되었다. 최근 수년간 디터니즘을 바탕으로 한 인공지능기법이 급격히 발전함에 따라 빅데이터라고 불릴 수 있는 정도로 대규모의 디지털화된 영상 자료의 처리와 분석에도 인공지능이 활발히 연구 및 적용되고 있다.

의료 영상 분석의 결과는 환자의 치료에 직접 적용되기 때문에 과정이나 결과가 남용가능해야 하고 학문적으로 타당해야 한다. 인공지능은 수학적 이론에 바탕을 두고 있으므로 의료 영상 분석을 위해 영상 자료 특성에 따라 적절한 인공지능 모델의 선택과 영상 전처리 및 결과의 해석에 모두 수학적인 지식이 필요하다. 따라서 기존의 의료 영상 분석에는 의학적 지식을 바탕으로 의사 주도로 이뤄졌다면 최근의 의료에는 다양한 학문적 협력이 더욱 요청되고 있으며, 인공지능이 일반화됨에 따라 더욱 그러한 경험을 보인다.

핵의학 영상에서 대표적 검사인 양성자방출단층촬영 (Positron Emission tomography, PET) 영상의 재구성에 인공지능을 적용하여 문제를 해결하였던 경험을 나눔으로써 더 활발한 학문간의 상호협력을 기대한다.

Short scanning image restoration of brain amyloid PET

영상 복원 (Image restoration)은 사진 속의 노이즈나 이물질 또는 혼들림에 의해 영상이 깨끗하지 못하거나 저화질의 영상을 고화질의 깨끗한 영상으로 복원하는 것을 말하며. 많은 연구들에서 인공지능 기법을 사용하여 영상 복원을 시도하였다. 최근에는 일반 영상뿐만 아니라 의료 영상에서도 인공지능 기법의 영상 복원에 관한 연구들이 활성화되어 있고, 일부 기술들은 이미 상용화단계에 진입하고 있다 [1, 2].

핵의학 검사인 PET 검사는 종양, 뇌신경, 신장, 감염 질환 등의 여러가지 목적으로 병원에서 사용되고 있는데, 최근에는 앞서히며 치매의 원인으로 알려져 있는
베타아밀로이드가 논속에 축적되어 있는 것을 PET 검사를 이용해 영상으로 전단하고 있다.

그동안 부검을 통해서만 확인할 수 있었던 비정상단백질을 영상 검사로 확인할 수 있기에 때문에 매우 좋은 검사이지만 20분 정도 운동이 없이 활명하는 것이 인지기능이 감소한 환자에게는 너무 힘든 일이고 실제로 검사 중 운동이 임해 활명을 하거나 검사하는 것이 힘들어 검사를 포기하는 경우도 있어, 검사 시간을 짧게 하는 것이 필요하다. 그러나 촬영 시간을 짧게 하면 획득된 데이터의 양이 적어서 영상의 질이 나빠져 관독에 사용할 수 없다는 문제점이 있다. 인공지능을 이용하여 이러한 문제를 해결하고자 하였으며, 2분간 짧게 촬영하여 얻은 저화질의 영상을 영상 복원 기법을 사용하여 20분간 활성한 것과 같은 고화질로 복원하고자 하였고, 국가수리과학연구소와 협업하여 문제 해결을 시도하였다.

![The schematic diagram of the generative adversarial network](image)

**그림 1. The schematic diagram of the generative adversarial network**

딥러닝 모델은 Generative Adversarial Network (GAN)을 사용하였고, 모델 구조는 위의 그림과 같다. 인공지능을 통해 만들어진 영상은 아래와 같이 육안으로 보기에도 매우 원본과 유사한 영상을 얻었다.

![Amyloid PET images](image)

**그림 2. Amyloid PET images. 20-min ground-truth (left), 2-min short-scanning (middle) and synthetic (right) images**

인공지능기술을 통해 얻어진 영상이 원본과 유사한 지 그리고 의사들이 관독에 사용할 수 있는지를 확인하였다. 관독 의사 3명을 대상으로 Turing test를 시행하였고 20분간 얻은 원본 영상과 인공지능에 의해 얻어진 영상을 육안적으로 구분하지 못하였으며
(표 1), 인공지능을 통해 얻어진 영상을 이용하여 의사들이 판단을 하였을 때, 판단 정확도는 90% 정도를 보였으나(표 2) 일부 영상을 이용해 얻은 정확도와 큰 차이를 보이지 않았다.

### 표 1. Turing test

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4yrs exp non-MD</td>
<td>32/57 (56.1%)</td>
<td>26/58 (44.8%)</td>
</tr>
<tr>
<td>4yrs exp NM physician</td>
<td>25/57 (43.9%)</td>
<td>28/58 (48.3%)</td>
</tr>
<tr>
<td>Over 15yrs exp NM physician</td>
<td>36/57 (63.2%)</td>
<td>35/58 (60.3%)</td>
</tr>
<tr>
<td>Over 20yrs exp NM physician</td>
<td>25/57 (43.9%)</td>
<td>32/58 (54.2%)</td>
</tr>
</tbody>
</table>

### 표 2. Accuracy, sensitivity, and specificity in clinical reading. Data in parentheses are 95% confidence interval (%).

<table>
<thead>
<tr>
<th>Metric</th>
<th>Reader 1</th>
<th>Reader 2</th>
<th>Reader 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>91.4% (81.0, 97.1)</td>
<td>89.7% (78.8, 96.1)</td>
<td>86.2% (74.6, 93.9)</td>
<td>89.1%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>95.2% (83.8, 99.4)</td>
<td>88.1% (74.4, 96.0)</td>
<td>90.5% (77.4, 97.3)</td>
<td>91.3%</td>
</tr>
<tr>
<td>Specificity</td>
<td>81.3% (54.4, 96.0)</td>
<td>93.8% (69.8, 99.8)</td>
<td>75.0% (47.6, 92.7)</td>
<td>83.3%</td>
</tr>
</tbody>
</table>

미국의 대표적인 치매 연구 데이터베이스인 Alzheimer's Disease Neuroimaging Initiative (ADNI)의 amyloid PET data를 이용해 external validation을 시행하였을 때, 마찬가지로 유사한 결과를 얻어서 본 연구의 결과는 의미 있는 것으로 생각되며, 인공지능 기술을 사용하여 환자의 편의는 높이면서 고품질의 영상을 얻을 수 있음을 확인하였다. 이러한 내용을 통해 Scientific Reports에 발표하였다 [3].

**Generation of missing data of brain amyloid PET**

PET 검사가 가지는 가장 큰 특징이자 장점중 하나는 몸속에 있는 미량의 물질의 질량값을 살아있는 생체에서 영상 검사를 통해 측정할 수 있다는 점이다 [4]. 질량값의 측정을 위해서는 일반적인 촬영 방법이 아니라 방사성약품을 체내에 주사하면서 동시에 촬영이 시작되고 몸에서 배설이 일어나는 시점까지 동영상을 찍듯이 계속 영상 검사를 하고 있어야 하며, 이를 동적 데이터(dynamic data)라고 하며, kinetic 분석에 이용된다 [5]. Amyloid PET의 경우는 1시간 가량 연속적으로 촬영을 하여야 한다. 이 시간동안 환자는 움직임이 없이 누워있어야 하며, 이러한 검사상의 어려움 때문에 큰 장점에도 불구하고 일반적으로는 잘 사용하지 않고 있다.

![Dynamic data curves of amyloid PET images.](image-url)

**표 3. Dynamic data curves of amyloid PET images.** Conventional data curve (left) and proposed curve (right)
그림 3에서 보는 것과 같이 기존 방법으로 얻은 full-time 그래프가 일정한 경향을 가진 모습을 보이기 때문에 비교적 흔들림이 적은 중간시간대의 데이터는 생략하고, 초기 및 후기 데이터만을 얻어서 중간 시간대의 값을 수학적으로 예측하여 만들여낼 수 있다면 환자는 짧은 시간만 촬영하여 편의성을 높일 수 있으면서도 동적 검사의 장점을 살릴 수 있을 것으로 기대가 되며, 국가수리과학연구소와 함께 해결을 시도하였다.

정상인과 치매 환자 각 15명에게 60분간 얻은 full-time dynamic data를 정답으로 하고, 초기 15분과 후기 15분을 이용해서 중간 30분 데이터를 예측하도록 하였고, 예측된 값은 정답과 일치 정도를 평가하였다.

먼저 전체 그래프에 적용할 수 있는 지표함수를 정하였고, 각 환자의 데이터를 이용해 상수값을 예측하여 각 환자마다 최종 피팅 함수를 구하여 중간 시간대의 값을 예측하였다.

\[ c_0 + c_1 \log x + c_2 (\log x)^2 + c_3 \sqrt{\log x} + c_4 x = y \]
수식 1. 지배 함수

이러한 방법으로 얻어진 데이터(일부)는 아래 그림과 같다.

<table>
<thead>
<tr>
<th>정상인</th>
<th>피팅 함수</th>
</tr>
</thead>
</table>
| Normal 1 | 294.9992357815966 + 1483.2363321101915x - 313.695104690126 \( \log x \) + 2175.387518045604 \( \log x \) 
| Normal 2 | 7621.382666666666 - 8.25000000000001 \( \log x \) + 1277.385720939381 \( \log x \) + 1389.351870367996 \( \log x \) + 89.012996907129 \( \log x \) |
| Normal 3 | 17313.654356696966 + 368.654576846944 \( \log x \) - 468.298830448882 \( \log x \) - 638.565473899264 \( \log x \) - 2742.496053923534 \( \log x \) |
| Normal 4 | 2735.333333333333 + 13.19402835535118 \( \log x \) - 683.298909495261 \( \log x \) + 2441.505764656634 \( \log x \) - 824.658381026805 \( \log x \) |

그림 4. Examples of fitting functions of normal subjects (left) and fitting curve (right)

예측된 값들과 실제값들을 회귀분석을 통해 비교하였을 때, \( R^2 \) 값이 0.99 이상으로 확인되어 중간값을 잘 예측한 것으로 확인되었다.

<table>
<thead>
<tr>
<th>R-Square 확인</th>
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<tbody>
<tr>
<td>Normal</td>
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<td>13</td>
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<tr>
<td>14</td>
</tr>
<tr>
<td>mean</td>
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<tr>
<td>std</td>
</tr>
</tbody>
</table>

그림 5. Results of regression analysis
추가로 시행한 연구에서 전체 60 분 데이터 중에서 초기 10 분, 후기 10 분 데이터만으로도 중간의 40 분 데이터를 잘 예측하였다. 이러한 결과들을 볼 때, 수학적인 방법을 이용하여 기존의 60 분간 활용해야 했던 불편에서 처음과 나중 각 10 분간 활용하여 검사의 편의를 높이면서도 동적데이터 분석이 가능한 full-time 데이터를 획득할 수 있음을 확인하였다.

결론

현재 병원에서 사용되는 기술로는 해결이 어려웠던 ‘unmet need’를 수학적인 방법을 이용하여 해결하였으며, 단순히 연구 결과에 그치는 것이 아니라 일상 업무에 이용할 수 있을 정도의 결과임을 확인하였다. 병원에 여러가지 새로운 검사법들이 지속적으로 개발되어 사용되고 있으며, 대부분 검사에서 정확한 정량 평가를 중요하게 여기고 있다. 따라서 수학적인 방법과 혜석이 점차 중요해지고 있으며, 이러한 측면에서 의료와 수학이 함께 해결할 수 있고 해결해야 할 부분들이 많기 때문에 학문간 협업이 반드시 필요하다고 생각된다.

참고문헌

Metal Artifact Reduction with Shape Prior
for 3D Low Dose Maxillofacial CBCT Imaging

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ABSTRACT

This talk presents a deep learning-based metal artifact reduction (MAR) method for practical 3D low dose maxillofacial CBCT imaging, where sinogram data is notably affected by beam hardening, photon starvation, high noise, field-of-view truncation, and offset-induced data missing. The proposed method is designed to improve the quality of a maxillofacial CBCT image from metal-related artifacts that can significantly degrade the performance on downstream tasks for digital dentistry. To the best of our knowledge, as shape-prior for MAR, this study attempts for the first time to take advantage of oral scan data containing substantial and accurate 3D surface information of teeth and gingiva. The proposed method comprises three steps: (i) Deep learning-based 3D sinogram-inpainting is performed along metal traces to compensate beam hardening and photon starvation-induced data contamination. (ii) To further remove metal-related artifacts, a 3D image-to-image deep learning network is employed, which takes advantage of oral scan data as shape-prior via multi-task learning. (iii) A 3D maxillofacial image is obtained by a weighted thresholding using oral scan data and alpha shape-based method, which can reduce the remaining streaking artifacts around teeth.

The other contribution is fully automated real-like paired data generation for supervised learning, where a paired dataset is generated in a way of artificially producing metal artifacts with automatically performing virtual surgery on many normal patients’ data.
Unpaired-paired learning for scattering correction in Cone-beam Computed Tomography

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ABSTRACT

Cone-beam computed tomography (CBCT) has been widely utilized in dental and maxillofacial imaging. However, the artifacts due to photon scatter, which appear primarily as bright and dark shadows in the reconstructed image, interfere with the diagnostic process. Recently, the generative adversarial network (GAN) has been used to learn the image correction function from unpaired artifacts-free and artifacts-affected images. To keep the morphological structure, $l_1$ or $l_2$ loss between generated image by network and artifact-affected image are used as a data fidelity (we call it fidelity-embedded GAN). However, such fidelity has difficulty in capturing the complicated scattering structure, and hence it sometimes causes unexpected artifacts. In this paper, we introduce a simple manual data processing to reduce these unexpected artifacts. We first learn the fidelity-embedded GAN using unpaired CBCT and multi-detector computed tomography (known to be nearly scatter-free) images. Based on the domain knowledge, we then manually choose the corrected CBCT that are not affected by unexpected artifacts, which appear as bone-like structures throughout this paper, and corresponding original CBCT images. Finally, using the paired samples, we retrain the fidelity-embedded GAN. The results show that the proposed approach substantially reduces not only the scattering artifacts but also the bone-like artifacts arising from the incorrect data fidelity, while preserving the morphological structures of the original CBCT image. In addition, the corrected image obtained by the proposed method enables more accurate bone segmentation compared to the original CBCT image.
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Special Session

Numerical Analysis and Machine Learning

- Minam Moon (Korea Military Academy)
- Chohong Min (Ewha Womans University)
- YoungKyu Lee (KAIST)
- Hee Jun Yang (Kyung Hee University)
Deep learning approaches for generalized multiscale finite element method

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ABSTRACT

Generalized Multiscale finite element method (GMsFEM) is in the spotlight as a model reduction technique for fluid analysis in heterogeneous and high-contrast porous media. The main factor of GMsFEM is how to generate a multiscale basis function. In GMsFEM, generalized eigenvalue problem is mainly used as a local problem to generate a multiscale basis function in each coarse neighborhood. However, the permeability of porous media is very diverse, and GMsFEM has the hassle of re-computing the multiscale basis function when the permeability changes. The objective of this research is to use deep learning technique to find the nonlinear relation between the permeability field and the multiscale basis functions in GMsFEM. The approaches enables fast and quick final calculations by finding a multiscale basis function quickly and easily through sufficient learning even if the permeability field changes.

REFERENCES

Convergence analysis on Deep Neural Networks

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ABSTRACT

In this talk, we review two conventional analyses on DNNs. One is an analysis to guarantee the monotonic decrease of error function, and the other is to guarantee the convergence of weights as long as the decrease of the error function.
Two-level Group Convolution

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ABSTRACT

Group convolution [1] has been widely used in order to reduce the computation time of convolution, which takes most of the training time of convolutional neural networks. However, it is well known that a large number of groups significantly reduce the performance of group convolution. In this presentation, we propose a new convolution methodology called “two-level” group convolution that is robust with respect to the increase of the number of groups and suitable for multi-GPU parallel computation. We first observe that the group convolution can be interpreted as a one-level block Jacobi approximation [2] of the standard convolution, which is a popular notion in the field of numerical analysis. In numerical analysis, there have been numerous studies on the two-level method that introduces an intergroup structure that resolves the performance degradation problem without disturbing parallel computation. Motivated by these, we introduce a coarse-level structure which promotes intergroup communication without being a bottleneck in the group convolution. We show that all the additional work induced by the coarse-level structure can be efficiently processed in a distributed memory system. Numerical results that verify the robustness of the proposed method with respect to the number of groups are presented. Moreover, we compare the proposed method to various approaches for group convolution in order to highlight the superiority of the proposed method in terms of execution time, memory efficiency, and performance.

REFERENCES

TWO-LEVEL DOMAIN DECOMPOSITION ALGORITHMS FOR PHYSICS-INFORMED NEURAL NETWORKS

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ABSTRACT

Domain decomposition algorithms are proposed when training neural networks as a solution of partial differential equations (PDEs). The neural network consists of smaller independent networks, that are trained as solutions of partial differential equations in smaller subdomains. Each neural network is a physics-informed learning problem with two terms, the domain term and the boundary term, that make the desired solution satisfy the PDEs and corresponding boundary conditions [1]. The solution of the whole domain can then be obtained by solving the smaller problems iteratively and exchanging the subproblem information across the interface at each iteration step. The use of smaller independent networks speeds up parameter training but slows down the convergence of iteration. A coarse neural network with a smaller parameter set is included to speed up the convergence. The coarse neural network is then trained as a solution of PDEs in the whole domain using a coarse data set. Using a coarse data set, the coarse neural network is then trained to reduce a global residual loss. The coarse solution then can be used to accelerate the convergence in the iterative scheme. Convergence analysis for the proposed algorithms using a projection operator are included [2]. Numerical results are included to show the performance of the proposed method.

REFERENCES


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Applications of Mathematical Data Science in Industry

- Seunghwan Yang (NIMS)
- Jae-Hun Jung (POSTECH)
- Yun Young Choi (NIMS)
- Jeong Rye Park (Pusan National University)
ESTIMATION OF PRICE PATTERNS IN APARTMENTS USING CLUSTERING

Minjung GIM\textsuperscript{1}, Dong Heon CHEO\textsuperscript{2} and Seunghwan YANG\textsuperscript{1}

\textsuperscript{1) Innovation Center for Industrial Mathematics, National Institute for Mathematical Sciences, KOREA
\textsuperscript{2) Samsung Electronics, KOREA}

ABSTRACT

The ICIM(Innovation Center for Industrial Mathematics) of NIMS(National Institute for Mathematical Sciences) has been at the forefront of discovering and solving mathematical problems that are encountered by industry in practice. In this talk, we deal with the case of solving industrial problem regarding sequential data of GINPLUS company. The company is a start-up company that provides information of real estate based on big data and requested an industrial problem to estimate a price pattern in low transaction apartments. We introduce this problem and the method to solve it mathematically. In addition, we provide an explanation of the K-Means clustering algorithm(K-Means) and a method to use the K-Means without mathematical problem. Finally, we will present the patterns estimation method for low transaction apartments using clustering.

REFERENCES

Topological Data Analysis of Korean Music in Jeongganbo and Machine Composition

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ABSTRACT

Jeongganbo is a unique music representation invented by Sejong the Great. Contrary to the western music notation, the pitch of each note is encrypted and the length is visualized directly in a matrix form in Jeongganbo. We use topological data analysis (TDA) to analyze the Korean music written in Jeongganbo for Suyeonjang, Songuyeo, and Taryong, those well-known pieces played at the palace and among noble community. We are particularly interested in the cycle structure. We first define and determine the node elements of each music, characterized uniquely with its pitch and length. Then we transform the music into a graph and define the distance between the nodes as their adjacent occurrence rate. The graph is used as a point cloud whose homological structure is investigated by measuring the hole structure in each dimension. We identify cycles of each music, match those in Jeongganbo, and show how those cycles are interconnected. The main discovery of this work is that the cycles of Suyeonjang and Songuyeo, categorized as a special type of cyclic music known as Dodeuri, frequently overlap each other when appearing in the music while the cycles found in Taryong, which does not belong to Dodeuri class, appear individually. Further we introduce our recent research on machine composition based on the cycles and patterns found through TDA.
Lithium-ion Batteries Model Identification under Various Operating Conditions

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ABSTRACT

Recently, electric vehicles (EVs) are widely used because of the need for eco-friendly transportation. Lithium-ion batteries (LIBs) represent the most used power sources in EVs among the types of rechargeable batteries. To safely operate the LIBs in EVs, it is indispensable to construct a reliable LIB model. Therefore, parameter identification (PI) from charge/discharge data becomes important as a cost-effective approach for estimating reliable model parameters. We identify model parameters from reference data under multi constant C-rates, dynamics stress test, and federal urban driving schedule. We demonstrate that the LIB model with identified parameters well represents the electrochemical characteristics of LIBs.
DEVELOPMENT OF AN ALGORITHM IMPROVING LABEL ARRANGEMENTS IN OFFSET PRINTING

장근수¹, 김태형¹, 김현민², 공기만⁴, 박정례¹⁵, 서충현⁵, 서상협³, 윤산원¹

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4) 월드코맥스, 부산 48059
5) CHUBU UNIVERSITY ACADEMY OF EMERGING SCIENCE, Japan

교신 저자: 서상협, saibie677@gmail.com

요약

One of the most classic problems in the manufacturing industry is inventory processing. There is a way to effectively reduce inventory by changing the array of pieces on the printing plates in the offset printing. It is done by setting an acceptable upper limit for each plate, and by carrying out complete enumeration. This method drastically reduces the operating time of the algorithm. The advantage of this method is that it focuses on changing the arrangement of the pieces on the plates.
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CJK–SIAM mini–symposium I Emerging Mathematics in AI

- Ernest K. Ryu (Seoul National University)
- Yingzhou Li (Fudan University)
- Taiji Suzuki (The University of Tokyo)
- Zaiwen Wen (Peking University)
WGAN WITH AN INFINITELY WIDE GENERATOR HAS NO SPURIOUS STATIONARY POINTS

Albert No\textsuperscript{1} Taeho Yoon \textsuperscript{2} Sehyun Kwon \textsuperscript{2} Ernest K. Ryu \textsuperscript{2}

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ABSTRACT

Generative adversarial networks (GAN) are a widely used class of deep generative models, but their minimax training dynamics are not understood very well. In this work, we show that GANs with a 2-layer infinite-width generator and a 2-layer finite-width discriminator trained with stochastic gradient ascent-descent have no spurious stationary points. We then show that when the width of the generator is finite but wide, there are no spurious stationary points within a ball whose radius becomes arbitrarily large (to cover the entire parameter space) as the width goes to infinity.

REFERENCES

Variational Training of Neural Network Approximations of Solution Maps for Physical Models

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ABSTRACT

A novel solve-training framework is proposed to train neural network in representing low dimensional solution maps of physical models. Solve-training framework uses the neural network as the ansatz of the solution map and trains the network variationally via loss functions from the underlying physical models. Solve-training framework avoids expensive data preparation in the traditional supervised training procedure, which prepares labels for input data, and still achieves effective representation of the solution map adapted to the input data distribution. The efficiency of solve-training framework is demonstrated through obtaining solution maps for linear and nonlinear elliptic equations, and maps from potentials to ground states of linear and nonlinear Schrödinger equations.
Benefit of deep learning: Efficiency of function estimation and its optimization guarantee

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1) Department of Mathematical Informatics, The University of Tokyo, Tokyo, Japan
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ABSTRACT

In this talk, I discuss how deep learning can statistically outperform shallow learning methods such as kernel methods from the viewpoint of statistical estimation. First, I will discuss the excess risk bounds of deep learning in the Besov space and its variants, in which sparsity and non-convex geometry of the target function space play the essential role. In particular, it is shown that deep learning can work for high-dimensional input while the linear estimators including kernel ridge regression suffers from curse of dimensionality. In the latter half, I present a deep learning optimization framework based on a noisy gradient descent in an infinite dimensional Hilbert space (gradient Langevin dynamics), and show generalization error and excess risk bounds for the solution obtained by the optimization procedure. The proposed framework can deal with finite and infinite width networks simultaneously unlike existing one such as neural tangent kernel and mean field analysis. Moreover, I will show that deep learning can avoid the curse of dimensionality in a teacher-student setting, and eventually achieve better excess risk than kernel methods.
Sketchy Empirical Natural Gradient Methods for Deep Learning

Minghan Yang \(^1\), Dong Xu \(^2\), Zaiwen Wen \(^1\), Mengyun Chen \(^3\) and Pengxiang Xu \(^4\)

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ABSTRACT

In this paper, we develop an efficient sketchy empirical natural gradient method (SENG) for large-scale deep learning problems. The empirical Fisher information matrix is usually low-rank since the sampling is only practical on a small amount of data at each iteration. Although the corresponding natural gradient direction lies in a small subspace, both the computational cost and memory requirement are still not tractable due to the high dimensionality. We design randomized techniques for different neural network structures to resolve these challenges. For layers with a reasonable dimension, sketching can be performed on a regularized least squares subproblem. Otherwise, since the gradient is a vectorization of the product between two matrices, we apply sketching on the low-rank approximations of these matrices to compute the most expensive parts. A distributed version of SENG is also developed for extremely large-scale applications. Global convergence to stationary points is established under some mild assumptions and a fast linear convergence is analyzed under the neural tangent kernel (NTK) case. Extensive experiments on convolutional neural networks show the competitiveness of SENG compared with the state-of-the-art methods. On the task ResNet50 with ImageNet-1k, SENG achieves 75.9% Top-1 testing accuracy within 41 epochs. Experiments on the distributed large-batch training show that the scaling efficiency is quite reasonable.
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Special Session

Biomedical Mathematics

- Jung-woo Chae (Chungnam National University)
- Jong Hyuk Byun (Pusan National University)
- Eunjung Kim (KIST)
- Jae Kyoung Kim (KAIST)
PK/PD modeling and its utilization in drug development and real-world data prediction

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ABSTRACT

In this talk, I will introduce the concept of Pharmacokinetic/pharmacodynamic (PK/PD) modeling and its utilization in drug development and the prediction of real-world data. PK/PD modeling and simulation can be used as an 'applied science' tool to provide answers on the efficacy and safety of new drugs faster and at a lower cost. PK/PD modeling can be used from the preclinical phase through all clinical phases of drug development. Furthermore, after the drug release in the market, the potential drug-drug interaction could be estimated with this tool. To perform the mentioned above, I will describe the Population PK(PD) modeling, physiologically-based pharmacokinetic (PBPK) modeling, and show the related projects done with pharmaceutical companies: 1) human PK prediction using allometric scaling method, 2) potential drug-drug interaction via in silico program. If the time is allowed, I will share the precision medicine project done with National University in Singapore team.

REFERENCES


Inference for a stochastic PKPD model via Approximate Bayesian Computation

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ABSTRACT

In the pharmacokinetic and pharmacodynamic model, parameter analysis is substantial to determine absorption, distribution, metabolism, secretion, and dosing regimen of drug. The deterministic or inference method of parameters is performed for model development based on data. In the deterministic case, parameter explorations are generally conducted by uniform, normal, gamma, or log-normal distributions locally or globally. Inference, on the other hand, is mainly carried out to derive posterior distribution using Bayesian method. In this study, we develop a stochastic target-mediated drug disposition model for TRX1 and phenytoin based on a stochastic process. Parameter inference of the model is performed by Approximation Bayesian Computation-Markov Chain Monte Carlo (ABC-MCMC) that uses likelihood-free method. ABC-MCMC supplement the difficulties of the deterministic or common Bayesian approach of parameters.

REFERENCES

Mathematical and computational modeling for better cancer treatment

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ABSTRACT

In this talk, we will discuss the integrated approach of mathematical/computational modeling, biological experimental, and the clinics to better understand and treat cancer. First, I will introduce model-driven adaptive therapy strategies. Here, we developed two models that explain two modes of interaction between drug-sensitive and -resistant cell populations in a tumor. The models were parameterized using serological biomarker data from patients with advanced melanoma. The trained models were used to determine patient-specific adaptive therapy on and off schedule, resulting in improved progression-free survival compared to a one-size-fits-all therapy strategy. Next, we will discuss a mathematical model of cell signaling pathways to predict targeted therapy outcomes. The model was trained by minimizing the difference between model-predicted protein expression and experimentally measured protein phosphorylation under different microenvironmental conditions. The calibrated model predicts distributional responses to kinase inhibitors and suggests drug resistance mechanisms that can be exploited in drug combination strategies. The suggested combination strategies are validated using in vitro experimental data. The validated in silico cells are further interrogated through an unsupervised clustering analysis and then integrated into a hybrid cellular automata model of tumor growth in a spatially heterogeneous microenvironment. As a proof of concept, we simulate tumor responses to targeted therapies in a spatially segregated tissue structure containing tumor and stroma and predict complex cell signaling responses that suggest a novel combination treatment strategy.

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Mathematical modeling and machine learning approach for sleep disorders.

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ABSTRACT

In this talk, I will illustrate collaborative stories between our math group and medical researchers to treat disrupted circadian rhythms and sleep. In collaboration with Pfizer Inc. to help the development of a new drug modulating circadian phase, we have used a mathematical model. In this talk, I will illustrate how we identified the major source of a large inter and intra-species variations in the efficacy of the clock-modulating drug by using the combination of in silico, molecular and behavioral experiments. To circumvent the large inter-patient variations, I will propose the “adaptive” chronotherapy identifying personalized dosing regimens that restore normal circadian phase. Furthermore, in collaboration with Samsung medical center, we have analyzed complex sleep patterns of shift workers with a mathematical model to find optimal sleep patterns improving their sleep quality. This opens the chance for the development of an app providing personalized sleep schedule based on sleep patterns measured by wearable devices. If time is allowed, I will briefly introduce the phenotyping of Obstructive sleep apnea based on whole PSG data rather than a single canonical metric, AHI.

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Program

Special Session

CJK-SIAM mini-symposium II Mathematical modeling of emerging infectious diseases

- Hyojung Lee (NIMS)
- Yanni Xiao (Xi’an Jiaotong University)
- Takashi Tsuchiya (National Graduate Research Institute for Policy Studies)
- Jin CHENG (Fudan University)
Forecasting the spread of COVID-19 according to the effect of interventions in Republic of Korea

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ABSTRACT

The novel coronavirus outbreak has rapidly spread out from Wuhan, Hubei Province, China to other countries since December, 2019. The World Health Organization (WHO) declared the COVID-19 outbreak a global pandemic on March 11, 2020. More than 130,000 cases have confirmed since the first case was reported on 20 January, 2020 as of 31 May 2021 in South Korea. The Korean government implemented the combined interventions including social distancing, and work-at-home policies. In this research, first, the epidemiological characteristics are analyzed in seven geographical areas in Korea. Second, we construct a mathematical model to estimate the effective reproduction numbers by geographical area, which assess the effect of control interventions. Finally, we forecast the COVID-19 cases under the different effect of control interventions using mathematical model approach on the COVID-19 spread.
Multi-scale mathematical models of the COVID-19 pandemic

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Abstract: The global outbreak of COVID-19 has caused worrying concern amongst the public and health authorities. Modeling of this novel coronavirus also presents us a great challenge. In this talk I initially summarize what we have done on the prediction of COVID-19 pandemic and effect of massive movement on the possible outbreak [1,2]. I then present our recent work on COVID-19 infection, including a multi-scale models describing the multiple outbreaks and a stochastic individual based model on complex networks with four layers. We would like to investigate how behavior changes, vaccination and relaxation of non-NPIs affect the development of COVID-19 infections. Finally I shall give some considerations and thoughts on modelling COVID-19 infections and concluding remarks. This is joint work with Prof Tang Sanyi and Prof Wu Jianhong and their groups.

Reference
A SIMPLE MATHEMATICAL MODEL ON SPREAD OF COVID-19 AND ITS APPLICATION TO JAPAN

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ABSTRACT

The spread of Covid-19 causes serious damages to Japanese society since 2020. In this talk, a simple mathematical model is presented to describe spread of Covid-19 used to predict the number of day-by-day new cases in Tokyo and Osaka. The prediction has been posted on a homepage of the speaker, updated once in a week or two weeks, and has been picked up for broadcast on nationwide TV networks several times when the situation got serious. The used data for prediction is simple, day-by-day number of new cases in Tokyo and Osaka, and day-by-day number of cases based on the date of onset in Tokyo. The dynamics of infection is described with a simplified version of SIR model, where the period of infection of a patient is assumed to be a constant instead of obeying to an exponential distribution. The model also takes into account of the delay from exposure to development and then to announcement to public. It is shown that the model works reasonably well in spite of its simplicity. We consider that this simplicity is important, since it enables more people to understand the nature of the dynamics and hence may help critical decision makers of the country to take effective countermeasures at the right timing.
A linear nonlocal model for outbreak of COVID-19 and parameter identification

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ABSTRACT

The novel corona virus pneumonia (COVID-19) is a major event in the world. Whether we can establish the mathematical models to describe the characteristics of epidemic spread and evaluate the effectiveness of the control measures we have taken is a question of concern. From January 26, 2020, our team began to conduct research on the modeling of new crown epidemic. A kind of linear nonlocal dynamical system model with time delay is proposed to describe the development of covid-19 epidemic. Based on the public data published by the government, the information of transmission rate, isolation rate and other information, which may not be directly observed in the process of epidemic development is obtained through inversion method, and on the basis of that, a "reasonable" prediction of the development of the epidemic is made. To provide some reasonable data support for government decision-making and various needs of the public.
KSIAM 2021 Spring Conference
Korean Society for Industrial and Applied Mathematics

June 25–27, 2021
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Gangneung, Korea

Program

Special Session

Cell Motility

- Sookkyung Lim (University of Cincinnati)
- Lee, Wanhoo (NIMS)
- Yangjin Kim (Konkuk University)
- Hyungmin Jun (Jeonbuk National University)
How do flagellated bacteria swim?

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ABSTRACT

Bacterial motility mediated by flagellar rotation is one of the most ubiquitous swimming strategies in the world of microorganisms. Many species of flagellated bacteria navigate the fluid environment as they interact with the physical and chemical microenvironment for biological processes, and their swimming patterns are mostly characterized by the number and the arrangement of flagella over the cell body. In this talk, I will introduce different types of microorganisms that are propelled by flagella and show how they reorient in a free space and modify their swimming paths in the presence of physical barrier.
Computational simulation of E. coli propelled by bacterial flagella

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ABSTRACT

Peritrichously flagellated bacteria swim in a fluid environment by rotating motors embedded in the cell membrane and consequently rotating multiple helical flagella. We present a novel mathematical model of a microswimmer that can freely run propelled by a flagellar bundle and tumble upon motor reversals. Our cell model is composed of a rod-shaped rigid cell body and multiple flagella randomly distributed over the cell body. These flagella can go through polymorphic transformations. We demonstrate that flagellar bundling is influenced by flagellar distribution and hence the number of flagella. Moreover, reorientation of cells are affected by the number of flagella, how many flagella change their polymorphisms within a cell, the tumble timing, different combinations of polymorphic sequences, and random motor reversals. Our mathematical method can be applied to numerous types of microorganisms and may help to understand their characteristic swimming mechanisms.

REFERENCES

Collective migration of glioma cells through signaling in the presence and absence of reactive astrocytes and stem cells after surgery

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ABSTRACT

Glioblastoma multiforme (GBM) is the most aggressive type of brain cancer with a short median survival time. GBM is characterized by the hallmarks of aggressive proliferation and cellular infiltration of normal brain tissue. In particular, we previously showed that (i) intracellular component such as myosin II is important in regulating cellular invasion of glioma cells between normal cells of brain by immersed boundary method [1] (ii) aggressive invasion of cancer cells is the critical step of cellular metastasis and low survival rate in many cancers [2]. Cellular processes such as haptotaxis and chemotaxis through extracellular signaling such as glucose were shown to control the migration patterns of glioma cells in the *in vitro* environment [3]. miR-451 and its downstream molecules are known to play a pivotal role in regulation of the balance of proliferation and aggressive invasion in response to metabolic stress in the tumour microenvironment (TME) [4]. Many players in TME such as immune cells play an important role in designing new anti-tumor strategies. For example, recently we showed that use of natural killer cells has to be carefully designed in order to avoid therapeutic conflicts with other effective strategies such as bortezomib (anti-cancer drug) or oncolytic viruses [5,6] through mathematical modeling and validation with experiments [7]. Our recent study also showed that neutrophils and its special structure called NET can mediate cellular invasion of cancer cells and metastasis to other organ [8]. Therefore, it is important to understand the critical role of cells in TME in order to develop a new therapeutic drug. Astrocytes themselves [9] and surgery-induced transition in reactive astrocyte populations [10] can play a significant role in tumour dynamics. Here, we introduce a multi-scale mathematical model that represent the dynamics of the miR-451-LKB1-AMPK-OCT1-mTOR pathway signalling and individual cell dynamics of the tumour and reactive astrocytes after surgery [11]. We illustrate how the effects of fluctuating glucose on tumour cells need to be reprogrammed by taking into account the recent history of glucose variations and an AMPK/miR-451 reciprocal feedback loop. The mathematical model shows how variations in glucose availability significantly affect the activity of signalling molecules and, in turn, lead to critical cell migration in GBM. The results from the simulation are consistent with experimental observation [10]. The model also predicts that microsurgery of a primary tumour...
induces phenotypical changes in reactive astrocytes and stem cell-like astrocytes promoting tumour cell proliferation and migration by Cxcl5. We also investigated a new anti-tumour strategy by Cxcl5-targeting drugs.

REFERENCES


세포 군집 이동을 모사하기 위한 연속체역학 기반 유합요소 모델링

Continuum-based Finite Element Modeling for Collective Cell Migration

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Abstract

본 연구에서는 단백질 농도에 따른 군집세포 군집 이동을 모사하는 유합요소(Finite Element) 기반 수학 모델을 제안한다. 세포군집의 대변형(Large Deformation)을 고려하기 위해 초탄성(Hyperelastic) 제료 모델을 고려하였고, 외연적(Explicit) 시간적분(Time integration)을 적용하여 동적시스템에 대한 수치해석 계산의 효율성을 증가시켰다. Total Lagrangian 수식화를 통해 대변형 및 제로 비선형에 대한 유합요소 정식화를 수행하였다. Traction Force Microscopy를 통해 Hepatocyte Growth Factor의 농도 변화에 따른 세포 군집의 이동을 실험적으로 확보하였고, 개발된 수학모델의 타당성 검증에 사용되었다.

Materials and Methods

세포군집의 이동을 모사하기 위한 유합요소 모델은 아래의 식과 같이 비선형 운동방정식으로 표현된다(1-3).

\[
\begin{align*}
M' \ddot{U} + K'(U) \cdot U &= R \\
M' \ddot{U} &= R - F
\end{align*}
\]

\(M\) 은 질량 행렬, \(K\) 는 강성(Stiffness) 행렬, \(R\) 은 외력벡터, \(F\) 내부 힘 벡터(Internal force vector), \(U\)는 가속도 벡터, 그리고 \(U\)는 변위(Displacement) 벡터이다. \(K\)는 비압축성(Incompressible) 대변형 탄성문제를 고려한 초탄성 제료모델을 내포한다. 본 연구에서는 Rubber-like 재료에서 자주 활용되는 Mooney-Rivlin 모델을 채택하였다. 세포집단은 프리즘(Prism) 유합요소를 통해 이산화(Discretization) 되었으며, 외연적 시간적분을 통해 컴퓨터 계산속도를 향상시켰다(2).

개발된 수학모델을 검증하기 위해, Fluorescent bead를 가진 Elastic gel에 세포층을 도포하고 Traction Force Microscopy를 이용하여 세포들의 Traction force와 운동을 관찰하는 실험을 진행하였다. Motorized live cell imaging system을 사용해 시계열 영상을 수집하고, PIV code를 이용하여 세포 영상의 플레시에 따른 세포의 이동속도, 방향, 채도 등을 정량적으로 분석하였다.

유합요소기반 세포이동 모델을 활용하여, Hepatocyte Growth Factor(HGF)의 농도 변화에 따른 세포군집의 변위 및 동력을 계산하였고 실험데이터와 비교 분석을 진행하였다(그림 1).
Discussions

본 연구에서는 세포의 집단적 이동에 대한 가상실험 시스템을 개발하였다. 세포 집단을 Continuum medium 으로 모델링하는 방안을 제안하였고, 초단성 재료 모델 및 외연적 시간적분을 고려한 유한요소 모델을 개발하였다. HGF 농도 변화에 따른 세포 집단이동 및 음력변화에 대한 컴퓨터 시뮬레이션을 수행하였고 실험데이터와의 검증을 진행하였다. 실험과 해석 결과를 비교하여 개발된 수학모델이 세포 군집이동을 잘 모사할 수 있음을 보였다.

Acknowledgment

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Program

Special Session

Mathematics of Geosciences

- Sehun Chun (Yonsei University)
- Sung-Ik Sohn (Gangneung-Wonju National University)
- Sangil Kim (Pusan National University)
- Young Jin Kim (NIMS)
SWE conservational error caused by geometric approximation error on the spherical earth

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**ABSTRACT**

The vertices of curvilinear elements usually lie on the exact domain. However, the additional grid points introduced for the higher-order polynomial of numerical solution often are located slightly out of the domain to generate geometric approximation error. Considered the main cause of the conservational error, this error is relatively smaller than discretization error but large enough to significantly deteriorate a long time integration. This phenomenon is particularly striking for a conservational PDE such as the shallow water equations (SWEs) on a closed surface like the 2-sphere, as an approximation of the Earth. In this talk, we propose a novel scheme with geometry-aligned moving frames and the removal of corresponding spurious divergence to reduce the conservational error caused by geometric approximation error.

![Figure 1](image1.png)

Figure 1. Geometric approximation error (left) and Rossby-Haurwitz wave on the sphere (right).

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Modeling of Jet Streams and Polar Vortex on a Rotating Sphere

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ABSTRACT

Jet streams and polar vortex are the prominent flow structures observed on Earth and gas planets such as Jupiter and Saturn. Understanding how the jet and vortex structures persist and become unstable is fundamentally important, particularly in weather forecasting. In this talk, we discuss the stability of jet streams and polar vortex on a rotating sphere. The jet stream and polar vortex are modelled by a barotropic vortex strip and vortex cap, respectively, using the contour dynamics model. We present the linear stability of the vortex strip and the vortex cap and investigate the dependence of the stability on the strip width, rotation speed, and vorticity constants. Computational results on the nonlinear evolution of the vortex strip and vortex cap are also demonstrated. Large structures of roll-up and filamentation evolve in the vortex strip and vortex cap. Furthermore, we address the geophysical relevance of the model to planetary jet streams.

Figure 1. Evolution of the vortex strip as a model for a jet stream.

REFERENCES

자료동화 소개

Data Assimilation: Predicting the Unpredictable

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요약

많은 학문분야에서 수치모델의 초기값을 보다 정확하게 추정함으로써 미래예측의 정확도를 향상시키는 문제를 다루고 있다. 자료동화는 이러한 목적을 이루기 위해 많은 분야에서 활용되고 있다. 자료동화의 개념은 이해를 돕기 위해 개별적인 자료동화의 개념과 방법론들을 소개한다. 특히, 자료동화 방법론 중 가장 쉽게 수행해 볼 수 있는 양상자료동화에 대해서는 다양한 이론과 수행 방법 등을 함께 소개한다.

자료동화의 개념과 종류

물리현상들의 특성과 정량을 이해하는 방법으로 사용되고 있는 많은 방법들 중 가장 많이 활용되고 있는 두 가지 방법이다. 하나는 직접 관측한 자료를 활용하는 방법이고 다른 하나는 수치모델을 활용하여 물리현상을 재현하는 방법으로 그 특성과 정량을 이해하는 방법이다. 관측된 자료의 특성은 물리현상을 대표하는 가장 정확한 값으로 물리현상의 참값으로 받아들이고 있다. 다른, 이러한 자료와 관측한 결과의 시간적 어려움으로 인해 부분적으로만 이루어지며, 관측장비에 존재하는 대표성 오차는 항상 존재하고 있다는 점을 염두에 두어야 한다. 수치모델을 활용할 방법은 모델명역과 해상도를 조절함으로써 물리현상을 전체적으로 표현할 수 있고, 관측방법보다는 상대적으로 시간과 비용이 적으며 현상의 정량과 정량을 쉽게 이해할 수 있다는 특성이 있다. 반면, 관측된 수치모델의 결과가 정확하게 물리현상을 재현하고 있는지에 대한 검증이 반드시 필요하다. 왜냐하면 수치모델내에는 다양한 오차가 존재하고 있기 때문이다. 예를 들면 방정식을 이산화하는 방법, 수치모델에서 정의된 매개변수와 상수들의 불확실성, 수치모델의 입력장인 초기조건과 경계장에서 오는 오차 등이다. 정증방법으로는 관측된 자료를 활용하여 자료와 모델결과를 비교 분석하는 방법이 가장 많이 활용되고 있다.

자료동화는 수치모델의 결과와 관측자료를 활용하여 보다 정확하게 물리현상을 재현하는 방법론으로 이해될 수 있다. 즉, 관측된 자료와 수치모델의 결과를 수학적 통계적 방법을 사용하여 파거 및 현재, 미래의 물리현상을 추정하는 학문이다. 과거 물리현상을 추정하는 것을 hindcasting 또는 smoothing problem, 현재 물리현상의 추정은 nowcasting 또는 filtering problem, 그리고 미래 물리현상 추정은 forecasting 또는 prediction problem이라고 불린다. 이러한 용어의 차이는 분야별로 조금씩 다르지만, 포괄적인 개념은 같다. 지구과학 분야에서 주요 관심사가 보다 정확한 초기조건의 개선을 통해 미래물리현상을 정확하게 예측하고자 그 이유에 자연동화방법도 초기조건의 개선에 초점을 맞점이 맞
추가되는 filtering problem을 해결하는 방법이 주요 관심사이다.

필터링문제 (filtering problem)는 크게 두 가지 범주의 자료동화 방법으로 나누어 진다. 하나는 변분자료동화방법이며, 다른 하나는 양상분자료동화방법이다. 예를 들어 0시 에서 6시까지의 주어진 시간 구간안에서 메시마다 자료가 관측되고 있다고 하자. 필터링문제는 마지막 시간인 6시에의 모델 조기장을 구하는 문제가 된다. 변분자료동화방법은 주어진 시간 구간안의 모든 자료들의 값과 수치모델결과 값의 차이를 최소자승법의 비용함수로 표현하고, 최소화과정을 통해 비용함수가 최소가 되도록 하는 조기장을 찾는 방법이다. 3차원 변분법 및 4차원 변분법 (3/4 variational method), 대표변분법 (representer method) 등이 대표적으로 사용되고 있다 (Daley 1991; Courtier 1997; Bennett 1992, 2002). 양상분자료동화방법은 주어진 시간 구간의 최초시간에서 유효변수를 대표하는 N개의 모델조기장을 구성한 후, 각각의 조정을 모델조기장으로 하여 모델을 수행하는 방법을 통해 최종 시간인 6시에서의 조기장을 추정한다. 대표적인 방법으로는 파티클필터 (Particle filter) 및 양상분할필터 (Ensemble Kalman Filter), 양상분할필터 (Ensemble Tranform Kalman Filter) 등이 있다 (Gordon 1993; Doucet et al. 2001; Evensen 2009).

양상분 자료동화 과정

양상분 자료동화에서는 공통적으로 3단계 과정인 초기화, 예측, 갱신(분석)으로 나누어 진다. 먼저, 초기화 과정에서는 N개의 조기장을 먼저 생성하는 단계이며, 예측 단계에서는 N개의 조기장을 이용하여 수치모델을 시간적분하는 단계이다. 모델 적분은 자료가 관측되는 시간까지 수행된다. 자료가 관측되었을 때, 수행된 N개의 모델결과, 또는 모델 결과들의 평균값을 배경장이라 부른다. 이러한 배경장과 관측자료에 대해 베이스이론을 적용함으로써 새로운 N개의조기장을 만들어 낸다. 이 과정을 갱신(분석)단계라하며, 갱신된 N개의 조기장 또는 평균값을 분석장이라고 부른다. N개의 분석장은 다시 다음 모델과정을 위한 조기장으로 활용된다. 요약하면, 양상분 자료동화는 초기과정에서 N개의 양상불을 생성한 후, 자료가 관측되는 시간에는 갱신단계를 거치고, 자료가 없는 시간에는 예측단계를 반복적으로 수행하는 자료동화 방법이다. 이러한 양상분자료동화의 주요한 핵심은 갱신단계에서 활용되는 베이스이론을 어떻게 각각의 양상불에 적용느냐이다. 적응 방법에 따라 다양한 양상분자료동화방법이 만들어 지게 된다. 이중 대표적으로 사용되고 있는 파티클필터 (Particle Filter)와 양상분할필터 (Ensembl Kalman Filter)의 갱신단계를 발표에 소개한다.

요약

양상분 자료동화에서는 공통적으로 3단계 과정인 초기화, 예측, 갱신(분석)으로 나누어 진다. 먼저, 초기화 과정에서는 N개의 조기장을 먼저 생성하는 단계이며, 예측 단계에서는 N개의 조기장을 이용하여 수치모델을 시간적분하는 단계이다. 모델 적분은 자료가 관측되는 시간까지 수행된다. 자료가 관측되었을 때, 수행된 N개의 모델결과, 또는 모델결과들의 평균값을 배경장이라 부른다. 이러한 배경장과 관측자료에 대해 베이스이론을 적용함으로써 새로운 N개의 조기장을 만들어 낸다. 이 과정을 갱신(분석)단계라하며, 갱신된 N개의 조기장 또는 평균값을 분석장이라고 부른다. N개의 분석장은 다시 다음 모델과정을 위한 조기장으로 활용된다. 요약하면, 양상분 자료동화는 초기과정에서 N개의 양상불을 생성한 후, 자료가 관측되는 시간에는 갱신단계를 거치고, 자료가 없는 시간에는 예측단계를 반복적으로 수행하는 자료동화 방법이다. 이러한 양상분자료동화의 주요한 핵심은 갱신단계에서 활용되는 베이스이론을 어떻게 각각의 양상불에 적용느냐이다. 적응 방법에 따라 다양한 양상분자료동화방법이 만들어 지게 된다. 이중 대표적으로 사용되고 있는 파티클필터 (Particle Filter)와 양상분할필터 (Ensembl Kalman Filter)의 갱신단계를 발표에 소개한다.
참고문헌

Sea level rise estimation near the Korean peninsula using CEEMDAN with tidal data

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ABSTRACT

The sea level rise due to global warming is an issue at a global level and its causes already have been studied clearly in early times. IPCC creates scenarios for greenhouse gas emissions and predicts global average sea level rise accordingly. Ice Sheet System Model is a numerical model of ice sheet dynamics process caused by the loss of ice sheets in polar regions. In particular, the global sea level rise prediction through the Glacial Isostatic Adjustment provides seawater flows from the ice sheet at a macroscopic scale. However, this global scale modeling has limitations in insufficient mesh size due to computation speed and makes it difficult to predict local differences in sea level rise in microscopic scale and complex terrain. In particular, in the Korean Peninsula, high sea level rise rate differences between tidal stations have been reported in microscopic areas (\(\sim 100\) km). In this study, we study regression and empirical mode decomposition for sea level rise prediction using tidal data near Korean Peninsula. And we also analyze correlation, causality, and volatility to understand the difference between tidal stations.
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General Session I

- Dohyun Kim (Yonsei University)
- Sanghee Lee (Yonsei University)
- Seungchan Ko (University of Hong Kong)
- Chun Jae Park (Konkuk university)
STAGGERED DG METHOD WITH SMALL EDGES FOR DARCY FLOWS IN FRACTURED POROUS MEDIA

Lina Zhao\textsuperscript{1}, Dohyun KIM\textsuperscript{2}, Eun-Jae PARK\textsuperscript{2} and Eric CHUNG\textsuperscript{1}

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ABSTRACT

In this talk, Darcy flows in fractured porous media are considered. We assume that flows in the bulk domain and on the fractures follow Darcy’s law. Because of geometric characteristic of fractures, they can be considered as one-dimensional objects. In turn, we have two-dimensional Darcy’s equation in the bulk domain coupled with one-dimensional problems along the fractures. We apply a staggered DG method on polygonal mesh for the bulk domain and use the standard conforming finite element method for the fractures. We remove one typical assumption on polygonal meshes, the smallness of edges, in \textit{a priori} error estimates. This theoretically supports the robustness of staggered DG methods so that our methods work even on polygonal meshes with poor quality. We conducted numerical tests to verify the optimal convergence of the proposed method. Also, a benchmark problem is proposed to test the effect of small edge to the numerical solution. Our method behaves robustly and the convergence behavior is independent of existence of small edges. We also present numerical experiments with meshes obtained by cutting background meshes by fractures. While these meshes contain small edges and sliver elements, we observe optimal convergence rates for all variables with respect to degrees of freedom.
An expanded staggered DG for the heterogeneous diffusion equation

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ABSTRACT

In this talk, we present an expanded staggered discontinuous Galerkin method for the heterogeneous diffusion problem on general polygonal meshes and a suitable a posteriori error estimator. In groundwater hydrology, the diffusion tensor may tend to be zero and its reciprocal is not usable. To resolve the problem, the expanded formulation introduces an intermediate variable, pressure gradient. It helps us to avoid the inversion of the diffusion coefficient. We derive a priori and a posteriori error estimates. A priori error estimates prove the optimal convergence rates in $L^2$-norms for the pressure, the flux, and the pressure gradient. Residual-based a posteriori error estimates are conducted and a reliable and efficient error estimator is suggested. We consider three numerical experiments to examine convergence behaviors, robustness to mesh distortion, and the performance of the proposed a posteriori error estimator. The results indicate that our method behaves robustly on general meshes even when there are small edges or slim elements. Also, the effectivity index of the proposed method is reasonably small in a strong anisotropy case, compared to that of the standard staggered discontinuous Galerkin method.

REFERENCES

Finite element approximation of an incompressible chemically reacting non-Newtonian fluid

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ABSTRACT

We consider a system of nonlinear partial differential equations modelling the steady motion of an incompressible non-Newtonian fluid, which is chemically reacting. The governing system consists of a steady convection-diffusion equation for the concentration and the generalized steady Navier–Stokes equations, where the viscosity coefficient is a power-law type function of the shear-rate, and the coupling between the equations results from the concentration dependence of the power-law index. This system of nonlinear partial differential equations arises in mathematical models of the synovial fluid found in the cavities of moving joints. We construct a finite element approximation of the model and perform the mathematical analysis of the numerical method in the case of two and three space dimensions respectively. Key technical tools include discrete counterparts of the Bogovski˘ı operator, De Giorgi’s regularity theorem in two dimensions, and the Acerbi–Fusco Lipschitz truncation of Sobolev functions, in function spaces with variable integrability exponents.

REFERENCES

**Successive finite element methods for Stokes equations**

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**ABSTRACT**

We will suggest a new economic finite element method for Stokes equations. Its main character is the local successive steps for the pressure. For an example, in $P^4 - P^3$ case, a $P^3$-pressure $p_h$ is calculated in 5 steps consisting of 4 local and 1 global systems as in figure 1. The chief time cost of the new method is on solving two separated linear systems. One is for the velocity and the other is for the $P^0$-pressure.

![Figure 1. successive pressures calculated in $8 \times 8 \times 4$ mesh](image)

- (a) $\bar{p}_h$ calculated from local systems
- (b) $p^C_h$ calculated from a global system
- (c) a pressure solution $p_h = \bar{p}_h + p^C_h$

Figure 1. successive pressures calculated in $8 \times 8 \times 4$ mesh
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**General Session II**  

- Younhee Lee (Chungnam National University)  
- Tae-Kyoung Kim (Chonnam National University)  
- Jeonggyu Huh (Chonnam National University)  
- Bongyeong Koo (Seoul National University)
Irreversible investment decision problem with jumps on finite time horizon

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ABSTRACT

A real option on finite time horizon is considered under a regime-switching jump-diffusion model. The investor wants to determine an optimal investment time to maximize the discounted expectation of a payoff function. In this talk, the value of a project is evaluated by solving a partial integro-differential equation (PIDE) and it can be expressed as a closed-form solution. Then the value function and the optimal investment time can be computed by using an operator splitting method. A number of numerical simulations are performed to compute the value function and to find the optimal time to invest in the project.
ACCURATE AND EFFICIENT COMPUTATION OF IMPLIED VOLATILITIES USING NEURAL NETWORK

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ABSTRACT

Implied volatility, letting the Black-Scholes price equal to the market price, is considered as a normalized indicator of an option price. Because of that, it is well-known that it is desirable to employ an implied-volatility-based loss for model fitting. However, obtaining the implied volatilities of enormous options iteratively needs too high computation costs. To resolve the difficulty, Peter Jäckel proposed asymptotic formulas for the implied volatility [1][2]. Then, to correct the estimates more exactly, iterative methods were applied to the estimates such as Newton's method. By doing so, it was possible to compute the enormous implied volatilities quite quickly. Nevertheless, the computation time should be reduced more in the view of the practice. So a few researchers tried to make neural networks to estimate the implied volatilities [3][4]. It was a novel and interesting approach, but they could not achieve the networks performing with high accuracy within a wide domain. In this study, we made the network to estimate the implied volatilities so exactly within a wide domain. Our method is so efficient that it is applicable in practice. This implies that the major issues of the preceding studies are addressed enough. This is possible because the experiment was designed to preclude the possibility of generalization errors. Powerful GPU machines were also another important factor for the improvement since an extensive network could be trained using so large simulated data due to them. Furthermore, as Peter Jäckel did, the estimates of the network were corrected very exactly using an iterative method.

REFERENCES


Extensive networks would eliminate the demand for pricing formulas

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ABSTRACT

In this study, we generate a large number of implied volatilities for the Stochastic Alpha Beta Rho (SABR) model using a graphics processing unit (GPU) based simulation and enable an extensive neural network to learn them. This model does not have any exact pricing formulas for vanilla options, and neural networks have an outstanding ability to approximate various functions. Surprisingly, the network reduces the simulation noises by itself, thereby achieving as much accuracy as the Monte-Carlo simulation. Extremely high accuracy cannot be attained via existing approximate formulas. Moreover, the network is as efficient as the approaches based on the formulas. When evaluating based on high accuracy and efficiency, extensive networks can eliminate the necessity of the pricing formulas for the SABR model. Another significant contribution is that a novel method is proposed to examine the errors based on nonlinear regression. This approach is easily extendable to other pricing models for which it is hard to induce analytic formulas.

REFERENCES


Using feature pyramid information for weakly supervised object localization

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ABSTRACT

Weakly supervised object localization (WSOL) means that finding the location of object without bounding box labels. In this condition, many WSOL methods have been proposed complex optimization. To overcome this limitation, we suggest a novel architecture that making use of feature pyramid information [1]. The proposed network strengthens the representation of feature map, which leads to increased performance as well as more simpler optimization.

REFERENCES

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General Session III

- Youngsuk Ko (Konkuk University)
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- Eunha Shim (Soongsil University)
- Hongkyu Yoon (UNIST)
Mathematical modeling of COVID-19 considering heterogenous transmission and vaccination in the Republic of Korea: from the initiation to herd immunity

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ABSTRACT

Pandemic COVID-19 has caused serious economic burden and breakdown of medical system worldwide. Since the first large-scale epidemic have been occurred in Europe, various vaccines have been developed. In December 2020, AZD1222, known as the Oxford-AstraZeneca vaccine, acquired emergency-use authorization and the vaccination initiated in England. In Korea, minimizing mortality and forming a herd immunity in 2021 are set as prior objects and the first vaccination began on February 26, 2021. In this study, we discuss about effective vaccination strategy by the two different point of view, short-term and long-term. The total population is divided differently as the point of view changes. For short-term and long-term, four heterogeneous groups (healthcare worker, underage, adult, and senior) and five age groups (0-17, 18-29, 30-59, 60-74, and 75 years old or older) are considered, respectively. Maximum likelihood estimation was used to estimate the transmission rate between different groups, and the estimated transmission rate matrix was applied into the mathematical model including vaccination. For the short-term (or long-term), the model was simulated until February 25, 2021 (or most recent date) and extended by 100 days (or until December 31, 2021) with various scenarios. As results, both of short-term and long-term analysis emphasize the importance of maintaining adequate social distancing controls along with sufficient vaccine supply, in order to simultaneously and effectively achieve the mortality minimization and the formation of herd immunity in 2021.

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OPTIMAL CONTAINMENT STRATEGY FOR CANCER

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ABSTRACT

Continuous therapy, a standard of care in cancer treatment, often selects for a drug-resistant cell population, resulting in rapid treatment relapse. Recently, evolution-based adaptive therapy has been shown to improve survivals in both preclinical experiments and clinics. In this study, we use an agent-based modeling approach to investigate the impact of spatial competition on the adaptive therapy outcome. We model adaptive therapy with timed on and off of treatment. Treatment is applied to a tumor until the tumor volume to half of the initial volume, then treatment holidays are allowed until the tumor grows back to the initial volume. Our analyses show that the superiority of adaptive therapy over continuous therapy is modulated by the spatial distribution of resistant cells and fibroblast as well as migration and carrying capacity. Also, we investigate the role of initially undetected metastases on the treatment outcome. Further, we use optimal control to shape the intratumor competition to delay the tumor growth with optimal dose and compare the result with continuous and adaptive therapy outcomes.
Impact of COVID-19 variants on vaccination program in South Korea

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ABSTRACT

Two doses of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccines are currently administered in South Korea; however, vaccine supply is limited. We evaluated the impact of a coronavirus disease (COVID-19) vaccination campaign using single doses on reducing incidence, ICU hospitalization, and deaths in South Korea, considering constraints in vaccine supply and the emergence of variant strains. We developed an age-structured model of SARS-CoV-2 transmission parameterized with Korean demographics and age-specific COVID-19 outcomes. In our model, we considered a higher transmissibility of SARS-CoV-2 variant compared to pre-existing strain, and reduced vaccine efficacy against the variant. Vaccination program is expected to reduce the overall attack rate with the highest relative reduction observed among individuals aged ≥ 70 years. Even in the presence of a variant, vaccination is expected to reduce the overall attack rate. Our results indicate that vaccination can have a substantial impact on mitigating the COVID-19 outbreaks. However, herd immunity is unlikely to be achieved with the administration of a single dose of COVID-19 vaccine, especially with the potential emergence of SARS-CoV-2 variants.
NEURODYNAMICAL ROLE OF STDP IN STORAGE AND RETRIEVAL OF ASSOCIATIVE INFORMATION

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ABSTRACT

Spike-timing-dependent plasticity (STDP) is a biological process in which the precise order and timing of neuronal spikes affect the degree of synaptic modification. While there has been numerous research focusing on the role of STDP in neural coding, the functional implications of STDP at the macroscopic level in the brain have not been fully explored yet. In this work, we propose that STDP in an ensemble of spiking neurons renders storing high dimensional information in the form of a ‘memory plane’. Neural activity based on STDP transforms periodic spatio-temporal input patterns into the corresponding memory plane, where the stored information can be dynamically revived with a proper cue. Using the dynamical systems theory that shows the analytic relation between the input and the memory plane, we were able to demonstrate a specific memory process for high-dimensional associative data sets. In the auto-associative memory task, a group of images that were continuously streamed to the system can be retrieved from the oscillating neural state. The second application deals with the process of semantic memory components that are embedded from sentences. The results show that words can recall multiple sentences simultaneously or one exclusively, depending on their grammatical relations. This implies that the proposed framework is apt to process multiple groups of associative memories with a composite structure.
KSIAM 2021 Spring Conference
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Program

General Sessions

General Session IV

- Jongho Park (KAIST)
- Gwanghyun Jo (Kunsan National University)
- Sungha Yoon (Korea University)
- Hyuntae Cho (Seoul National University)
Fast Gradient Methods for Uniformly Convex and Weakly Smooth Problems

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ABSTRACT

In this paper, acceleration of gradient methods for convex optimization problems with weak levels of convexity and smoothness is considered. Starting from the universal fast gradient method [1] which was designed to be an optimal method for weakly smooth problems whose gradients are Hölder continuous, its momentum is modified appropriately so that it can also accommodate uniformly convex and weakly smooth problems. Differently from the existing works [2], fast gradient methods proposed in this paper do not use the restarting technique but use momentums that are suitably designed to reflect both the uniform convexity and the weak smoothness information of the target energy function. Both theoretical and numerical results that support the superiority of proposed methods are presented.

REFERENCES

Numerical simulation of Poisson-Boltzmann-Nerst-Plank model based on structured grid

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ABSTRACT

We introduce a new type of numerical method for Poisson-Boltzmann-Nerst-Plank model [1]. To treat the non-linearity we adopt the concept of Gummel’s methods. We solve Poisson-Boltzmann equation based on the concept of discontinuous-bubble immersed finite element method. Nerst-Plank equation is solved via control volume method. We provide numerical experiments regarding the ion-channel simulation. Our methods is robust with respect to location and numbers of the ion charges.

Reference
A linear convex splitting method to a high-order Cahn–Hilliard equation

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ABSTRACT

We present a linear convex splitting method to a high-order Cahn–Hilliard (CH) equation in this paper. The dynamics of the conventional CH equation on the shape of interface is sensitively affected to the size of mesh; the order parameter can be shifted between the minimum values of the double-well potential near the interface since it does not satisfy the maximum principle. Therefore, we use high-order free energy potentials to overcome this drawback and employ an unconditionally energy stable method. Furthermore, there is a weak point to use the conventional linear convex splitting method directly because the stabilized factor becomes too large when high-order potentials are employed, we modify the non-physical part of potentials as a function dependent on orders.

INTRODUCTION

In this study, we present an unconditionally energy stable linear convex splitting method for the Cahn–Hilliard (CH) equation with a high-order polynomial free energy. The following is the conventional CH equation,

\[
\begin{align*}
\phi_t(x, t) &= \Delta \mu(x, t), \quad x \in \Omega, \; t > 0, \\
\mu(x, t) &= F'(\phi(x, t)) - \epsilon^2 \Delta \phi(x, t),
\end{align*}
\]

where the order parameter \( \phi \) represents the difference of two concentrations in a binary mixture, \( \mu \) is the chemical potential of \( \phi \), the polynomial potential function \( F(\phi) \) is defined as \( 0.25(\phi^2 - 1)^2 \), and a model parameter \( \epsilon \) is concerned with the interfacial energy. Note that the two common boundary conditions are homogeneous and periodic boundary conditions. The CH equation is a \( H^{-1} \)-gradient flow of the following Ginzburg–Landau free energy functional:

\[
\mathcal{E}(\phi) = \int_{\Omega} \left[ F(\phi) + \frac{\epsilon^2}{2} |\nabla \phi|^2 \right] \, dx.
\]

Recently, the authors in [1] introduced the modification of the reaction part \( F(\phi) \) in Eq. (3) to investigate the effect of interface deformation in phase separation with fluid flow. In a similar manner, we employ the corresponding high-order polynomial free energy throughout this paper,

\[
F^m(\phi) = 0.25(\phi^{2m} - 1)^2,
\]
where $m$ is a positive integer. Figure 1 depicts the polynomial function, $F^m(\phi) = 0.25(\phi^{2m} - 1)^2$ for each different order $m = 1, 2, 3,$ and $10$. The bulk free energy is penalizing the shifting and stiff near from the local minimum values as the value of $m$ increases. The main advantage of adopting the high-order polynomial free energy is to overcome the drawback of the quartic polynomial one; a drop, whose radius is smaller than critical value, shrinks spontaneously.

The main purpose of this paper is to present a stable linear convex splitting (CS) scheme for the CH equation with a high-order polynomial free energy. The key idea is splitting an energy functional into two convex parts ($E(\phi) = E^c(\phi) - E^e(\phi)$, where $E^c(\phi)$ is a contractive part and $E^e(\phi)$ is an expansive part) and $E^c(\phi)$ and $E^e(\phi)$ are numerically treated implicitly and explicitly, respectively, i.e.,

$$\frac{\phi^{n+1} - \phi^n}{\Delta t} = -\nabla E^c(\phi^{n+1}) + \nabla E^e(\phi^n).$$

**NUMERICAL SOLUTION ALGORITHM**

We present the convex linear splitting method to the CH equation in this section. Firstly, we modify the total energy Eq. (3) using the high-order polynomial free energy Eq. (4) as follows:

$$E(\phi) = \int_{\Omega} \left[ \frac{1}{4}(\phi^{2m} - 1)^2 + \frac{\epsilon^2}{2} |\nabla \phi|^2 \right] d\mathbf{x}.$$  

(6)

Using the variational approach, we have

$$\mu = \frac{\delta E}{\delta \phi} = m(\phi^{4m-1} - \phi^{2m-1}) - \epsilon^2 \Delta \phi$$

and then the continuity equation yields

$$\frac{\partial \phi}{\partial t} = -\nabla \cdot (-\nabla \mu) = \Delta \mu.$$  

(7)

Note that we employ the no-flux boundary condition to preserve the mass conservation property. Now we take a semi-discretization to time, let $\phi^n$ be an approximation of $\phi(x, n\Delta t)$, where $\Delta t$
is a discretized finite time step. Applying this to Eq. (7) with a linear splitting scheme, then we have
\[
\frac{\phi^{n+1} - \phi^n}{\Delta t} = \Delta \left[ m(\phi^n)^{4m-1} - m(\phi^n)^{2m-1} - \epsilon^2 \Delta \phi^{n+1} + \alpha(\phi^{n+1} - \phi^n) \right].
\] (8)

Therefore, we can split Eq. (6) into two parts, contractive and expansive,
\[
\mathcal{E}(\phi) = \mathcal{E}^c(\phi) - \mathcal{E}^e(\phi)
\]
\[
= \int_\Omega \left[ \frac{\epsilon^2}{2} |\nabla \phi|^2 + \frac{\alpha}{2} |\phi|^2 \right] dx - \int_\Omega \left[ -\frac{1}{4} (\phi^{2m} - 1)^2 + \frac{\alpha}{2} |\phi|^2 \right] dx,
\]
where the diffusion term is contractive and the other is expansive in this case. Employing Eq. (10) yields the non-increase discrete energy over time,
\[
\mathcal{E}(\phi^{n+1}) - \mathcal{E}(\phi^n) = \left[ \mathcal{E}^c(\phi^{n+1}) - \mathcal{E}^c(\phi^{n+1}) \right] - \left[ \mathcal{E}^e(\phi^n) - \mathcal{E}^e(\phi^n) \right]
\]
\[
= \left[ \mathcal{E}^c(\phi^{n+1}) - \mathcal{E}^c(\phi^n) \right] - \left[ \mathcal{E}^e(\phi^{n+1}) - \mathcal{E}^e(\phi^n) \right]
\]
\[
\leq \left( \frac{\delta}{\delta \phi} \left( \mathcal{E}^e(\phi^{n+1}) - \mathcal{E}^e(\phi^n) \right), \phi^{n+1} - \phi^n \right)
\]
\[
= (\mu, \Delta t \Delta \mu) = -\Delta t |\nabla \mu|^2 \leq 0,
\]
where we assumed that the expansive part \( \mathcal{E}^e(\phi) \) is convex. Therefore, we differentiate the expansive term with respect to \( \phi \) twice in order to determine \( \alpha \) as this term to be convex as follows:
\[
\frac{\delta^2 \mathcal{E}^e(\phi)}{\delta \phi^2} = -m(4m - 1)\phi^{4m-2} + m(2m - 1)\phi^{2m-2} + \alpha \geq 0. \] (12)

However, the range of the order parameter \( \phi \) may deviate the range \([-1, 1]\) because the CH equation does not satisfy the maximal principle, hence we may have \(|\phi| > 1\). Therefore, we truncate the phase domain of the polynomial potential \( F^m(\phi) \) as \([-1, 1]\) and define this function as \( F^m_1(\phi) \). Consequently, define \( F^m_2(\phi) \) as a low-order polynomial than \( F^m_1(\phi) \) in the remainder of the domain. Hence, we redefine the polynomial potential \( F^m(\phi) \) as follows:
\[
F^m(\phi) = F^m_1(\phi) + F^m_2(\phi)
\]
\[
= \frac{1}{4}(\phi^{2m} - 1)^2 \chi(|\phi| \leq 1) + \frac{m^2}{4}(\phi^2 - 1)^2 \chi(|\phi| > 1),
\]
where \( \chi(\cdot) \) is the characteristic function. Note that we choose \( F^m_2(\phi) \) that satisfies \( F^m_1(\pm 1) = F^m_2(\pm 1) \), \( (F^m_1)'(\pm 1) = (F^m_2)'(\pm 1) \), and \( (F^m_1)''(\pm 1) = (F^m_2)''(\pm 1) \). Figure 2 depicts \( (F^m_1)''(\phi) \) in \([-1, 1]\). Since it has the maximum value at both end points, we conclude that \( \alpha \) can be determined by Eq. (12) as follows:
\[
\alpha = m(4m - 1) - m(2m - 1) = 2m^2.
\] (14)

In order to define the numerical solution, we discretize a domain \( \Omega = [l_x, r_x] \times [l_y, r_y] \) which is defined in two-dimensional space. Let \( L_x = r_x - l_x, L_y = r_y - l_y \) be the length of \( x, y \) direction, respectively, and \( N_x, N_y \) be positive even integers. Therefore, we can define \( h_x = \)
Figure 2. Graph of \((F^m_1)''(\phi)\) in \([-1, 1]\).

Let \(L_x/N_x\) and \(h_y = L_y/N_y\) as the space step size for \(x\) and \(y\) direction, respectively. Furthermore, we denote discrete points as \((x_i, y_j) = (l_x + ih_x, l_y + jh_y)\) where \(0 \leq i \leq N_x\) and \(0 \leq j \leq N_y\) are integers. Let \(\phi^n_{ij}\) be an approximation of \(\phi(x_i, y_j, t_n)\), where \(t_n = n\Delta t\) and \(\Delta t\) be the time step size. For the given discrete approximations \(\{\phi^n_{ij} | i = 1, \ldots, N_x \text{ and } j = 1, \ldots, N_y\}\), the discrete Fourier transform of those is defined as follows:

\[
\hat{\phi}^n_{pq} = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} \phi^n_{ij} e^{-i(\xi_p x_i + \eta q y_j)}, \quad -\frac{N_x}{2} + 1 \leq p \leq \frac{N_x}{2}, \quad -\frac{N_y}{2} + 1 \leq q \leq \frac{N_y}{2},
\]

where \(\xi_p = \frac{2\pi p}{L_x}\) and \(\eta_q = \frac{2\pi q}{L_y}\). Note that \(i = \sqrt{-1}\). Consequently, the inverse discrete Fourier transform is defined as follows:

\[
\phi^n_{ij} = \frac{1}{N_x N_y} \sum_{p=-N_x/2+1}^{N_x/2} \sum_{q=-N_y/2+1}^{N_y/2} \hat{\phi}^n_{pq} e^{i(\xi_p x_i + \eta q y_j)}. \quad (15)
\]

Therefore, we deduce the following numerical solution from Eq. (8),

\[
\hat{\phi}^{n+1} = \hat{\phi}^n - \Delta t (\xi^2 + \eta^2) \left( f^m(\hat{\phi}^n) - \alpha \hat{\phi}^n \right) \frac{1}{1 + \alpha (\xi^2 + \eta^2) + \Delta t (\xi^2 + \eta^2)^2}, \quad (16)
\]

where \(f^m(\phi) = (F^m)'(\phi)\).

REFERENCES

A second-order method for solving incompressible Navier-Stokes equation on quadtree and irregular domains

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ABSTRACT

Solving incompressible Navier-Stokes equation on irregular domain and quadtree is quite a challenging problem. Existing works to solve the equation on quadtree are based on projection method, which is hard to be extended to the irregular domains. Furthermore, most of the methods are based on marker-and-cell grid layout, which, in turn, results non-trivial discretizations on hanging nodes. In this study, we present a numerical methods to solve incompressible Navier-Stokes equation on irregular domains and quadtree based on monolithic methods and collocated Arakawa B-grid. Various numerical experiment supports that the proposed method is second–order accurate and is applicable to wide range of problems.
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Program

General Sessions

General Session V

• Hoin Jung (Seoul National University)
• Jin Kyu Yu (KAIST)
• Jiho Hong (KAIST)
• Doosung Choi (KAIST)
Boundary Improvement Module for Binary Semantic Segmentation in Remote Sensing

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ABSTRACT

The convolutional neural network applications in remote sensing areas have been developed rapidly. Moreover, satellite image processing via semantic segmentation is becoming important to respond to human development and disaster. However, sometimes, extracted masks of building footprint or road have anfractuous boundaries because of impediments near the target object, regardless of the resolution of satellite imagery. For this reason, we propose a boundary improvement module for binary semantic segmentation containing an encoder-decoder convolutional neural network. The proposed approach concentrates on extracting edge features from objects adopting renowned neural network, holistically-nested edge detector (HED) [1]. This unit is attached to the encoder part while the last part of the entire network is maintained. The extracted edge features from the edge detecting unit and segmentation mask from the decoder are combined by boundary improvement module, which is located in the tail part of the whole network. By these additional two steps, edge detecting unit and boundary improvement module, the building extraction performance is enhanced in terms of F1 score and Jaccard score in various range of Ground Sample Distance (GSD), 0.3m ~ 2.7m. Moreover, the proposed can be adopted state-of-the-art architecture, which contains an encoder-decoder structure.

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Defect inspection in semiconductor images

Jinkyu Yu and Chang-Ock Lee

1) Department of Mathematical Sciences, KAIST, Daejeon 34141, Korea

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ABSTRACT

In this talk, we present an automatic inspection of defects in semiconductor images. We devise a statistical method to find the defect on homogeneous background from the observation that it has a log-normal distribution. If a computer aided design (CAD) data is available, we use it to construct a signed distance function and change the pixel values so that the average of pixel values is zero, so that the image has a homogeneous background. In the absence of CAD data, we devise a hybrid method consisting of a model based algorithm and two neural networks [1–3]. Model based algorithm uses singular value ratio to determine whether image has linear or complex structure. For an image with linear structured, we remove the structure along the dominant angle so that is has a homogeneous background. A complex structured image is inspected by the two neural networks.

REFERENCES


On the first Steklov-Dirichlet eigenvalue for eccentric annuli

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ABSTRACT
In this paper, we investigate the first Steklov–Dirichlet eigenvalue on eccentric annuli. The main geometric parameter is the distance $t$ between the centers of the inner and outer boundaries of an annulus. We first show the differentiability of the eigenvalue in $t$ and obtain an integral expression for the derivative value in two and higher dimensions. We then derive an upper bound of the eigenvalue for each $t$, in two dimensions, by the variational formulation. We also obtain a lower bound of the eigenvalue, given a restriction that the two boundaries of the annulus are sufficiently close. The key point of the proof of the lower bound is in analyzing the limit behavior of an infinite series expansion of the first eigenfunction in bipolar coordinates. We also derive a relation between the first eigenvalue and a sequence of eigenvalues obtained by a finite section method. Based on this relation, we also perform numerical experiments that exhibit the monotonicity for two dimensions.

REFERENCES

Analytic shape reconstruction of a conductivity inclusion by using Faber polynomials

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ABSTRACT
A inclusion in a homogeneous medium induces a perturbation for the background potential. This perturbation admits a series expansion whose coefficients are the so-called generalized polarization tensors (GPTs). GPTs are obtained from multistatic measurements. As a modification of GPTs, the Faber polynomial polarization tensors (FPTs) were recently introduced in two dimensions. In this presentation, we show two analytical methods for recovering the shape of a homogeneous inclusion from GPTs. First, we derive an explicit expression for the coefficients of the exterior conformal mapping associated with an inclusion, which allows us to accurately recover the shape of an inclusion with extreme or near-extreme conductivity. Secondly, we provide a shape information of an inclusion with arbitrary conductivity by considering the inclusion as a perturbation of its equivalent ellipse. With this shape information, one can approximate an inclusion of general shape with arbitrary conductivity.
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Program

General Sessions

General Session VI

Jun Ho Lee (Konkuk University)
Donggu Lee (Konkuk University)
Hyukpyo Hong (KAIST)
Role of neutrophil extracellular traps in regulation of lung cancer invasion: a Computational Model

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ABSTRACT

Lung cancer is one of the leading causes of cancer-related deaths worldwide and is characterized by hijacking immune system for active growth and aggressive metastasis. Neutrophils, which require establishing immune activity against tumors as the first line of defense, are damaged by tumor cells, which in many ways promote tumor invasion. The mutual interaction between a tumor and neutrophils from bone marrow or in blood induces the critical transition of the naive form, called the N1 type, to the more aggressive phenotype, called the N2 tumor-associated neutrophils (TANs), which then promotes tumor invasion. In this study, we investigate the mutual interactions between the tumor cells and the neutrophils that facilitate tumor invasion by developing a mathematical model that involves taxis-reaction-diffusion equations for the critical components in the interaction. These include the densities of tumor and neutrophils, and the concentrations of signaling molecules (TGFbeta-CXCL8-MMP) and structure such as neutrophil extracellular traps (NETs). We apply the mathematical model to a Boyden invasion assay used in the experiments to demonstrate that the N2 TANs can enhance tumor cell invasion by secreting the neutrophil elastase. We show (i) that the model can reproduce the major experimental observation on NET-mediated cancer invasion, (ii) how stimulated neutrophils with different N1 and N2 landscapes shape the metastatic potential of the lung cancers and (iii) that the efficacy of anti-tumor and anti-invasion drugs depend on N1 → N2 landscapes of stimulated neutrophils. The mathematical model tests several hypotheses to guide future experiments with the goal of the development of new anti-tumor strategies.

REFERENCES


Mathematical model of STAT signaling pathways in cancer development and optimal control approaches

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ABSTRACT

In many diseases, STAT family displays various responses, such as cellular immunity, apoptosis, proliferation, and differentiation. In this study, we investigate how an intracellular signaling network (STAT1, STAT3, Bcl-2, and BAX) regulates an important cellular fate, either anti-apoptosis or apoptosis. We developed a mathematical model of a signaling network using a set of ordinary differential equations. We show that network can generate a bi-stability condition so that it will induce either apoptosis or anti-apoptosis status of tumor cells. Then, we use this model to develop several anti-tumor strategies including injection of IFN-beta and DDP. The model provides a visual display of the complex behavior of a population of STAT and tumor in response to various IFN-beta and JAK stimuli. The simulation results from the mathematical model were show agreement with experimental data. In addition, the effect of anti-tumor drug administration is incorporated in the model in an effort to achieve optimal anti-tumor efficacy by optimal control theory.

REFERENCES

DERIVATION OF STATIONARY DISTRIBUTIONS OF BIOCHEMICAL REACTION NETWORKS VIA STRUCTURE TRANSFORMATION

Hyukpyo HONG\textsuperscript{1,2}, Jinsu KIM\textsuperscript{3}, Muhammad ALI AL-RADHAWI\textsuperscript{4}, Eduardo SONTAG\textsuperscript{4} and Jae Kyoung KIM\textsuperscript{1,2}

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ABSTRACT

Long-term behaviors of biochemical reaction networks are described by steady states in deterministic models, and stationary distributions in stochastic models. Unlike deterministic steady states, stationary distributions capturing inherent fluctuations of reactions are extremely difficult to derive analytically due to the curse of dimensionality. In this presentation, we introduce a newly developed method to derive stationary distributions from deterministic steady states by transforming reaction networks to have a special dynamic property based on chemical reaction network theory. Specifically, we merge nodes and edges to make a steady state complex balanced, i.e., the in- and out-flows of each node are equal, and then we derive a stationary distribution from the complex balanced steady state. Applying our approach to various networks, we identify robustness, sensitivity, and multi-modality of their stationary distributions. Importantly, we provide a user-friendly computational package, called CASTANET, that transforms BRNs and then analytically derives their stationary distributions.
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Program

General Sessions

General Session VII

- Byeongseon Jeong (Ewha Womans University)
- Youngjoon Hong (San Diego State University)
- Juhyun Kim (Seoul National University)
- Jaeyoung Park (Pusan National University)
QUASI-INTERPOLATION OF MULTIVARIATE FUNCTIONS ON SPARSE GRIDS

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ABSTRACT

The aim of this talk is to introduce a new quasi-interpolation method for the approximation of multivariate functions on sparse grids. The kernels of the quasi-interpolation are constructed from one-dimensional radial basis functions based on the polynomial reproducing property. It is shown that the proposed sparse approximation achieves almost the same convergence order as the optimal approximation on the full grid while using far less amount of data. We also present experimental results to support the superior performance of our method compared to the quasi-interpolation based on the Gaussian kernel.

SPARSE QUASI-INTERPOLATION

Sparse grids are not uniform but comprised of a union of directionally uniform subgrids as illustrated in Figure 1. The quasi-interpolant \( Q_{\ell,d} f \) to a given multivariate function \( f \) on a sparse grid \( G_{\ell,d} \) is constructed by a linear combination of quasi-interpolants \( Q_n f \) on subgrids \( G_n \) as

\[
Q_{\ell,d} f := (-1)^{d-1} \sum_{k=0}^{d-1} (-1)^k \binom{d-1}{k} \sum_{|n|=\ell+k} Q_n f.
\]

Figure 1. Sparse grid as a union of directionally uniform subgrids.

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Deep neural network for solving differential equations motivated by Legendre-Galerkin approximation

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ABSTRACT

Deep neural networks have been applied to help alleviate the computational cost that is associated with solving these systems. We explore the performance and accuracy of various neural architectures on both linear and nonlinear differential equations by creating datasets with the spectral element method. We implement a novel Legendre-Galerkin Deep Neural Network (LGNet) algorithm to predict solutions to various differential equations. By constructing a set of a linear combination of the Legendre basis, we predict the corresponding coefficients, $\alpha_i$, which successfully approximate the solution as a sum of smooth basis functions $u \simeq \sum_{i=0}^{N} \alpha_i \varphi_i$. As a computational example, linear and nonlinear models including two-dimensional equations with Dirichlet or Neumann boundary conditions are presented.
고차정확도 내재적 대와류모사를 위한 수치정확도에 따른 격자 조밀도 관계식 연구

ON THE RELATION BETWEEN SOLUTION APPROXIMATION ORDER TO GRID RESOLUTION FOR HIGH-ORDER IMPLICIT LARGE-EDDY SIMULATION

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요약

고차정확도 수치기법을 이용한 내재적 대와류모사의 효율적인 계산을 위해 Kriging 메타모델을 이용하여 수치정확도에 따른 격자 조밀도 관계식(Grid-Pk relation)을 제안하였다. 최근 고차정확도 수치기법이 급속도로 발전함에 따라 고차정확도 수치기법을 이용한 내재적 대와류모사를 이용한 몇몇 연구가 수행되었으나, 대부분의 연구들은 사용된 격자 조밀도에 대한 명확한 기준을 제시하지 않고 있다. 아직까지 고차정확도 내재적 대와류모사의 효율적인 계산을 위한 격자 조밀도에 대해 잘 알려져 있지 않은 상황이며, 때문에 많은 연구들이 격자 제작에 어려움을 겪고 있다. 본 연구의 목적은 고차정확도 내재적 대와류모사를 위한 격자 조밀도에 대한 데라진적인 관계식을 제안함으로써 이러한 문제를 해결하는 것이다. 먼저, Kriging 메타모델을 이용하여 각 수치정확도에 대해 $Re_c = 180$의 난류 케달 유동에서의 최적 격자 조밀도를 도출하였다. 최적화 과정의 효율성을 높이기 위해 난류 케달 유동의 전이 시간을 최소화하는 초기 조건을 도출하였다. 이를 기반으로 붕연속 갤러킨 기법을 이용해 여러 수치정확도(P2, P3, P4), 여러 격자 조건에서 난류 통계치들을 계산하였다. 계산된 평균 Streamwise 속도와 직접 수치 해석(Direct Numerical Simulation) 결과의 L2 오차를 목표함수로 정의하고, 자유도를 직접 수치 해석의 0.1%가 되는 제한조건 하에서 목적함수를 최소화하는 격자 조밀도를 계산하였다. 계산된 결과로부터 수치정확도에 따른 격자 조밀도에 대한 경험식을 도출하였으며, 이를 더 높은 수치정확도(P5, P6)와 더 높은 레이놀즈 수($Re_c = 395, 550$)에서 검증하였다.

수치 해석 방법

본 연구에서는 가장 널리 쓰이는 고차정확도 수치기법 중 하나인 붕연속 갤러킨(Discontinuous Galerkin: DG) 방법을 이용해 내재적 대와류모사(Implicit Large-Eddy Simulation: ILES)를 수행하였다 [1,2,3]. DG에 사용된 기저함수는 Gram-Schmidt 직교화 과정으로 계산하였다 [3]. ILES는 명시적 sub-grid scale 모델을 사용하지 않고 수치기법 자체의 수치정성을 sub-grid scale 모델로써 사용하는 기법이다. 수치 플러스는 Roe 플러스를 사용하였으며 점성 플러스의 차분은 BR2 방법을 적용하였다. 또한 계산 오차를 높이기 위해 5차 정확도 내재적 시간진전기법인 RODAS5(4)를 적용하였다 [4,5]. RODAS5(4)의 선형화된 방정식의 해를 계산하기위해 GMRES(Generalized Minimal RESidual) 방법이 ILU(0)(zero fill-in Incomplete LU factorization)과 함께 사용되었다.
نان류 채널 유동

격자 및 유동 조건
해석 영역은 채널 높이의 1/2를 δ라 정의할 때 streamwise, spanwise, wall-normal 방향으로 각각 4πδ, 4π/3δ, 26이며 streamwise, spanwise 방향으로 균일한 25×25×14 직육면체 격자로 차분하였다. 수치차분으로는 DG-P3를 사용하여 총 175,000개의 자유도(Degree of Freedom: DOF)를 갖는다. 격자 크기는 streamwise, spanwise 방향으로 각각 Δx∗ = 90.48, Δz∗ = 30.16이며 벽면 격자 크기는 Δy∗ = 14.4, SR(Stretch Ratio)은 20%이다. 이 때 +는 viscous length scale δv = ν/μ로 무차원화되었음을 의미한다. Streamwise 방향과 spanwise 방향으로 주기적 경계 조건을 적용하였으며 위아래 벽에는 고착 단열 벽면(no-slip adiabatic wall) 경계 조건을 적용하였다. 본 연구에서 계산한 난류 채널 유동의 friction Reynolds 수는 Re∗ = 180이다.

천이 시간 점감을 위한 초기 유동 조건
난류 채널 유동에서 초기 유동 조건에 따라 천이 시간이 5배까지 길어질 수 있다 [6]. 이를 최소화하여 최적화 과정에서 소요되는 계산 시간을 줄이기 위해 몇 가지 유동 초기 조건에 대해 천이 시간을 측정하였다. 계산 결과 (1)과 같이 streamwise 방향 속도를 P0 다항식 공간에 사영된 선형 함수로 초기화했을 때 가장 천이 시간이 짧았다. 이 때 II°는 P0 함수 공간으로의 사영 연산자를 의미하며, \( u_b = \int_0^{2\delta} u dy/2\delta \)로 정의된 bulk 속도를 의미한다.

\[ u(y) = \begin{cases} \left( \frac{4u_b(y/2\delta)}{\delta} \right), & \text{if } 0 \leq y < \delta \\ \left( \frac{4u_b(1+y/2\delta)}{\delta} \right), & \text{if } \delta \leq y \leq 2\delta \end{cases} \]  

(1)

격자 조밀도 최적화

본 연구에서 격자 조밀도는 벽면 격자 높이(Δy∗) wall-normal 방향 SR, spanwise 방향 격자 크기(Δz∗)로 정의하였고, 실제 변수의 개수를 줄이기 위해 streamwise 방향 격자의 spanwise 방향 격자 크기의 비율을 3:1로 고정하였다. DG-P2, DG-P3, DG-P4 각각에 대해 Latin Hypercube Sampling(LHS) 방법으로 선정한 실험점으로 Kriging 메타모델을 구성하였으며, Expected Improvement(EI) 방법으로 메타모델을 고도화시켰다. 각각의 경우에 대해 구성된 Kriging 메타모델에 대해 Genetic Algorithm(GA)을 이용해 최적화를 수행하였다.

목적 함수의 경우 아래 식 (2)와 같이 직접 수치 모사(Direct Numerical Simulation; DNS)[7]와의 streamwise 방향 속도 차이를 이용해 정의하였으며, 파도한 격자 조밀도를 피하기 위해 식 (3)과 같이 ILES의 DOF를 DNS의 0.1%로 제한하였다. 이 때 식 (2)에서 \( \langle \cdot \rangle \)는 시간 평균을 의미하며, \( \langle \cdot \rangle_0 \)는 streamwise-spanwise 평면에 대한 평균을 의미한다. 이에 따라 각각의 수치정확도에 대한 최적화된 결과를 표 2에 나타내었다. 수치정확도가 DG-P2에서 DG-P4까지 증가함에 따라 Δy∗, Δz∗는 증가하는 양상을 보이며 SR는 반대로 감소하는 경향을 보였다.

\[ f(\Delta y^*, SR, \Delta z^*) = \| \langle \vec{u} \rangle - \langle \vec{u}_{DNS} \rangle \|_2 \]  

(2)

\[ DOF_{k} \leq \frac{DOF_{DNS}}{1000} \]  

(3)

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표 1. Kriging 메타모델을 이용한 최적화 결과

<table>
<thead>
<tr>
<th>Order</th>
<th>$\Delta y_{w}^+$</th>
<th>SR</th>
<th>$\Delta z^+$</th>
<th>$\Delta x^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG-P2</td>
<td>8.7827</td>
<td>1.3500</td>
<td>28.1880</td>
<td>84.5640</td>
</tr>
<tr>
<td>DG-P3</td>
<td>12.6827</td>
<td>1.2798</td>
<td>39.9534</td>
<td>119.8602</td>
</tr>
<tr>
<td>DG-P4</td>
<td>17.7731</td>
<td>1.2078</td>
<td>50.0677</td>
<td>180.2031</td>
</tr>
</tbody>
</table>

수치정확도에 따른 격자 조밀도 관계

표 1에서 제시된 수치정확도에 따른 최적 격자 조밀도로부터 간단한 형태의 관계식을 도출하기 위해 아래 식 (4)，(5)와 같이 wall-normal 방향과 streamwise, spanwise 방향에 대하여 두 가지 equivalent 변수($\Delta y_{w}^+$, $\Delta z^+$)를 정의하였다. 이 때 DG-Pk에 대하여 $\Delta y_{w1}^+(k)$는 k+1개 점을 갖는 Gauss-Legendre 수치적분의 첫 번째 수치적분점이 $y^+ = 1$에 위치하도록 하는 벽면 격자 높이를 의미한다.

\[
\Delta y_{w}^+(k) = \frac{\Delta y_{w}^+}{\Delta y_{w1}^+(k)} \tag{4}
\]

\[
\Delta z^+(k) = \frac{\Delta z^+}{k+1} \tag{5}
\]

정의된 두 가지 equivalent 변수를 기반으로 아래 식 (6)，(7)，(8) (이하 Grid-Pk 관계식)과 같이 간단한 형태의 관계식을 근사적으로 도출하였다. 그림 1에서는 각 수치정확도에 대해 실제 최적화를 통해 얻은 최적 격자 조밀도 변수와 Grid-Pk 관계식으로부터 계산한 격자 조밀도 변수를 비교하였다.

\[
\Delta y_{w}^+(k) = \frac{12-k}{10} \tag{6}
\]

\[
SR(k) = 1.5 - 0.075k \tag{7}
\]

\[
\Delta z^+(k) = 9.8 \tag{8}
\]

검증 문제 해석

제안된 Grid-Pk 관계식을 더 높은 수치정확도와 더 높은 Reynolds 수에서 검증하기 위해 맞이 검증 문제를 해석하여 DNS 결과와 비교하였다. 비교한 결과 중 streamwise 방향 속도 평균을 그림 2에 나타내었으며 DNS 결과와 잘 일치함을 확인할 수 있다.

그림 1. Grid-Pk 관계식과 Kriging 모델로 계산한 최적값 비교
고차정확도 ILES에 있어서 그동안 알려지지 않았던 격자 조밀도에 관한 Grid-Pk 관계식을 도출하였다. 이 관계식은 $Re = 180$ 난류 채널 유동에서 DG-P2, DG-P3, DG-P4에 대해 Kriging 모델을 이용해 최적 격자 조밀도를 계산하여, 이를 바탕으로 근사적으로 도출한 관계식이다. Grid-Pk 관계식을 이용해 계산한 격자 조밀도로 더 높은 정확도와 더 높은 레이놀즈 수에 대해서 검증하여 DNS결과와 잘 일치함을 확인하였다. 이 관계식은 모든 유동 상황에서 항상 최적인 격자 조밀도를 나타내기 위함은 아니며, 고차정확도 수치기법을 이용한 내재적 대화류 모사에서 초기 격자 조밀도를 생성할 때의 근사적인 기준점으로 사용하기 위해 제안되었다. 이를 통해 이후 고차정확도 ILES는 이용한 연구에서 격자 생성 과정의 효율성을 높일 수 있을 것으로 기대된다.

후기

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참고문헌

인공신경망 기반 극초음속 경계층 선형 불안정성 예측 연구

STUDY ON PREDICTION OF LINEAR STABILITY OF HYPERSONIC BOUNDARY LAYER BASED ON ARTIFICIAL NEURAL NETWORK

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요약

극초음속 경계층 불안정성의 신속한 예측을 위한 인공신경망 모델을 생성하고, 하이퍼파라미터에 따른 예측정확도를 분석하고자 하였다. 다양한 유동 조건의 2차원 단일 랜프 외 극초음속 경계층에 대한 선형 안정성 방정식 해석을 수행하여 학습 데이터를 생성하였다. 학습된 인공신경망 모델이 선형 안정성 해석결과와 유사한 경향성을 예측함을 확인하였다. 향후 연구를 통해 다양한 최적의 하이퍼파라미터를 적용한 신경망 모델을 기반으로 경계층 천이점의 반경의적 예측에 적용해 볼 예정이다.

서론

경계층 천이하는 극초음속 비행체 표면의 공력가열 및 공력성능에 큰 영향을 미치는 요인이다.[1] 극초음속 비행체 개발에 있어서 경계층 천이점의 예측은 열공력성능 해석을 통한 생존성 확보 및 성능 향상에 의해 필수적이며, 천이 현상의 물리적 분석과 예측을 위한 기초연구로써, 천이발생의 원인인 불안정성에 대한 연구가 진행되어 왔다.

경계층 불안정성을 연구하는 방법은 크게 이론적 방법과 수치적 방법 및 실험적 방법으로 분류할 수 있다. 수치적 방법에는 LES 및 DNS 등의 전산유동해석방법이 있지만, 안정성 해석과 비교하여 많은 계산자원이 요구된다. 이론적 방법으로는 선형 안정성 이론(Linear Stability Theory, LST)이 대표적이다. 하지만, 이론적 방법인 안정성 연구를 위해서는 안정성 해석 코드 등이 별도로 요구되며, 사용상 임의짐이 높아 활용을 위해서는 전문가가 요구되는 단점이 있다.[2] 따라서, 안정성 해석 결과 데이터를 활용하여 기계학습 기반으로 한 모델을 생성함으로써 경계층 불안정성을 신속하게 예측할 수 있으며, 극초음속 비행체의 초기설계 및 성능해석 시 천이 예측이나 설계 변수에 따른 천이점 변화 분석에 유용하게 활용할 수 있을 것이다.

본 연구에서는 LST 해석을 기반으로 획득한 2차원 극초음속 단일랜프 외 극초음속 경계층에 대한 안정성 데이터베이스를 인공신경망 기반에 적용하여, 신속하고 정확한 불안정성 예측 가능성을 확인하고자 하였다.

연구 방법

해석 케이스 및 학습용 데이터 획득

본 연구전이 보유하고 있는 LST 코드[3]를 활용하여 다양한 조건에 대한 2차원 단일 랜프 외 극초음속 경계층 안정성 해석을 수행하고, 인공신경망 모델 학습을 위한 훈련용 데이터베이스를 구축하였다. 해석 조건으로는 고도 $H = 10 \sim 30\text{km}$ ($\Delta H = 5\text{km}$), 마하수 $M = 5.6$ 및 다양한 밈조건도 조건 $(T_w = 300K, 600K, 900K,\text{ 단열})$을 설정하였다. 각 유동 조건에 대하여 안정성 해석을 위한 축류 평균 유동량(mean flow)을 계산하였다.
중류 평균 유동장에 대해 LST 해석을 수행하여 그림 1과 같이 랩프면에 평행한 주유동 방향(\(\mathbf{x}\)) 각 위치에서의 Mack 2nd mode\(^4\) 교란의 공간 증폭률(spatial amplification rate)을 획득하여 훈련용 데이터를 생성하였다.

![Diagram](image)

그림 1. 해석 단일랩프 형상

경계층 두께(\(\delta_h\)), 경계층 끝단의 속도(\(u_e\)), 밀도(\(\rho_e\)), 온도(\(T_e\)), 레이놀즈 수(\(R_e\)), 마하수(\(M_e\)), 무차원 교란 주파수(\(w_e = \omega \delta_h / u_e\)) 및 경계층 끝단과 벽면의 온도 비(\(T_e / T_w\)), 총 8가지의 독립변수를 신경망 모델의 입력변수로 선정하였으며, 각 해당 조건에 대해 LST로부터 계산되는 공간 증폭률(\(-a_t\))을 종속변수로써 인공신경망의 출력(예측)변수가 되도록 훈련 데이터베이스를 구성하였다. 위치별 무차원 교란 주파수(\(\omega_e\))는 특정 교란에 대하여 식(1)과 같은 무차원 교란 주파수(\(F\))의 정의로부터 획득한 교란의 주파수(\(\omega\))를 해당 위치의 경계층 두께와 끝단 속도로 무차원화 한 값이다. (식(2))

\[
F = \frac{2 \pi f u_e}{(U_\infty)^2} \times 10^6
\]

\[
\omega_e = \frac{\omega \delta_h}{u_e}
\]

각 변수의 하체자 ‘\(e\)’는 경계층 끝단에서의 값을 ‘\(\infty\)’는 자유류의 값을 의미하며, 경계층 두께는 랩프 벽면에 수직인 방향(\(y\))에 대하여 자유류 및 해당 지점의 전 압력\((total enthalpy)\)의 비가 \(h_t/h_{\infty} = 0.995\)가 되는 높이로 정의하였다.

인공신경망 모델 생성을 위해 획득한 훈련용 데이터는 58,026개이며, 생성 모델의 검증을 위해 \(M=5.5, H=20\, km\) 조건에서 무차원 교란 주파수 \(F=80\)에 대한 데이터를 추가로 획득하였다.

인공신경망 모델 생성

인공신경망 모델에는 텐서플로우(tensorflow)기반의 오픈소스 덱러닝 API(Application Programming Interface)인 케라스(Keras)[5]를 사용하였다. 하이퍼파라미터에 따른 신경망 모델의 예측 정확도를 평가하기 위해 표 1과 같이 다양한 은닉층(hidden layer)과 노드(node)의 개수 및 활성 함수(activation function)를 사용하여 모델을 생성하였으며, 그 이외의 파라미터들은 고정값을 사용하였다.

<table>
<thead>
<tr>
<th>표 1. 인공신경망 모델 생성을 위한 하이퍼파라미터</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batch size</strong></td>
</tr>
<tr>
<td><strong>Learning rate</strong></td>
</tr>
<tr>
<td><strong>No. hidden layers</strong></td>
</tr>
<tr>
<td><strong>Weight initializer</strong></td>
</tr>
<tr>
<td><strong>No. nodes per layer</strong></td>
</tr>
<tr>
<td><strong>Optimizer</strong></td>
</tr>
<tr>
<td><strong>Activation functions</strong></td>
</tr>
<tr>
<td><strong>Epochs</strong></td>
</tr>
</tbody>
</table>
본 초록에서는 결정계수 \((\text{determinant coefficient}, R^2)\)가 0.99 이상인 케이스들 중 고정된 특성 윈덕 중 노드수와 활성함수 (\(\text{No. of nodes per layer} = 32, \text{activation function} = \text{Sigmoid}\))에 대하여, 윈덕 중 개수 (\(\text{No. of hidden layers}\)) 별 모델의 예측정확도 비교 예시를 제시한다. 표 2.는 윈덕 중 개수에 따른 결정계수 값을 보여준다.

- 표 2. 데이터베이스 및 윈덕 중 개수에 따른 결정계수
  (\(\text{No. nodes per layer} = 32, \text{Activation function} = \text{Sigmoid}\))

<table>
<thead>
<tr>
<th>No. of hidden layers</th>
<th>Training database</th>
<th>Testing database</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9918</td>
<td>0.8946</td>
</tr>
<tr>
<td>2</td>
<td>0.9968</td>
<td>0.9007</td>
</tr>
<tr>
<td>3</td>
<td>0.9983</td>
<td>0.9768</td>
</tr>
</tbody>
</table>

결과 분석

 윈덕 중 개수의 영향 분석
 윈덕 중 개수에 따른 각 모델의 증폭률 예측결과와 LST 결과를 비교하여 그림 2-3에 나타내었다. 예측한 증폭률에 대하여 식 (3)-(4)를 사용하여 \(\epsilon^N\)-method에서 사용되는 N-factor 곡선을 그리고 예측 정확도를 비교하였으며, 훈련용 데이터 결과 비교는 대표결과로 고도 \(H = 10km\), 마하수 \(M = 6.0\) 조건의 무차원 교란 주파수 \(F = 25\)에 대한 결과를 나타내었다.

\[
N = - \int_{x_0}^{x} \frac{a_i(x)}{\delta(x)} \, dx
\]

\[
\delta(x) = \sqrt{\frac{\mu_\infty x}{\rho_\infty U_\infty}}
\]

그림 2. 훈련용 데이터 비교 결과 : \(H = 10km, \, M = 6.0, \, F = 25\) (No. nodes per layer = 32, Activation function = Sigmoid)

그림 2.는 훈련용 데이터에 대한 결과 비교를 보여주고 있다. 그림 2-(a)를 보면, 윈덕중의 수가 많은 모델이 교란 증폭률이 0이 되는 중립점 (neutral point)을 더 잘 예측하는 것을 확인할 수 있다. 이는 표 2.를 통해 확인했던 훈련용 데이터에 대한 결정계수 값이 윈덕중의 수가 증가함수록 커지는 경향과 일치한다고 볼 수 있다. 하지만, 그림 2-(b)의 N-factor 곡선을 보면, 윈덕중 개수의 증가와 상대적으로 높은 결정계수가 실제 안정성 예측결과와의 유사성을 보장해 주지는 않음을 확인할 수 있다.
검증용 데이터에 대한 비교결과를 그림 3.에 나타내었다. 앞서 검증용 데이터 비교결과와 마찬가지로 생성된 모델이 LST 해석과 유사한 경향성을 예측함을 확인할 수 있지만, 결정계수 및 은닉층 개수의 증가가 무조건적으로 높은 결과 정확도를 보장하지 않음을 확인하였다.

<Testing database>

(a) 중폭률 예측 결과

그림 3. 검증용 데이터 비교 결과: $H = 20\, km$, $M = 5.5$, $F = 80$

(No. nodes per layer = 32, Activation function = Sigmoid)

(b) N-factor 예측 결과

결론

본 연구에서는 극초음속 경계층 불안정성의 신속 예측을 위한 인공신경망 기반 모델의 예측정확도를 확인하고 경계층 전이지점 예측에의 활용 가능성을 확인하고자 하였다. 학습된 인공신경망 모델이 선형 안정성 이론 해석결과와 유사한 교란 증폭률을 예측하는 것을 확인하였으며, 본 발표에서는 다양한 하이퍼파라미터에 대해, 최적화된 모델을 소개하고 $e^X$-method기반의 경계층 전이지점 예측 적절 결과를 소개할 예정이다.

후기

이 논문은 2021년도 정부(미래창조과학부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임(No. 2020R1C1C101318512).

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STABILITY ANALYSIS OF A THREE-DIMENSIONAL HOST-PARASITOID MODEL WITH LOGISTIC GROWTH FUNCTION

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ABSTRACT

In this paper, we consider a three-dimensional host parasite model with logistic growth function. The existence and uniqueness of equilibrium points are investigated. And analyze the conditions which equilibrium points are stable. Some numerical simulations explain our theoretical results in better way.

INTRODUCTION

Many ecological models consisting interspecific interactions are generated by differential and difference equations. The discrete-time ecological form with non-overlapping populations are better formulated than continuous-time form. The host-parasitoid models are one of such forms. The mathematical model for the interactions between a host and its parasitoid was first studied by Nicholson and Bailey[1]. The term parasitoids means a parasite which is free living as an adult but lays eggs in the larvae or pupae of the host. Hosts escaping parasitism increase their generation. Hosts that are successfully parasitized die but the eggs laid by the parasitoid may survive to be the next generation of parasitoids.

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(2) Paper in a journal

(3) Paper in a journal

(4) Paper in a journal

(5) Paper in a journal

(6) Paper in a journal

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(7) Paper in a journal
(8) Paper in a journal
(9) Paper in a journal
(10) Paper in a journal
(11) Book
A STUDY ON CONVOLUTIONAL NEURAL NETWORK FOR CLASSIFICATION OF BRAIN TUMORS

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ABSTRACT

Brain tumors are judged by classifying the images scanned by Magnetic Resonance Imaging (MRI), but manual examinations are error-prone. Therefore, automatic classification is performed using Machine Learning (ML) and Artificial Intelligence (AI). CNN is one of the typical ML of image classification. In ImageNet Large Scale Visual Recognition Competition (ILSVRC), various CNN models that improve accuracy were presented.

This poster introduces the theory of Convolutional Neural Network (CNN), and based on the theory, we apply Brain tumor images. For CNN model, we proposed the five ILSVRC wining models, AlexNet, VGGNet, ResNet, DenseNet, and EfficientNet, and limited loss function, optimizer, epoch and batch size for each model. As a result of application, DenseNet with training train images has the highest accuracy of 99.72%. And the model evaluation accuracy that DenseNet used as test images is also the highest. Secondly, AlexNet give a high accuracy of 92.75%. But as a result of applying test images to AlexNet, it shows a low accuracy of 48.22%. So, there is overfitting at AlexNet. Then VGG Net and EfficientNet showed an accuracy of around 30% in all epochs, and it is judged that Vanishing gradient occurred. Finally, in the case of ResNet, the accuracy is 33.45% in epoch 1, but the accuracy is 59.82% in the last epoch 50. Therefore, ResNet will be performed as the epoch becomes larger.

REFERENCES

Particle Filter and Ensemble Kalman Filter for Stochastic ODE

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ABSTRACT

In this study, particle filters and ensemble Kalman filters are compared among filtering methods. To compare the two filters, we use a nonlinear model, a double well potential model. The double well potential model represents two stable states with $x = \pm 1$. However, by random fluctuations, the stable state can be converted to another state. We compare through experiments to see if the two filters follow these state transitions well. The experiment results show that the ensemble Kalman filter performs well with a low number of ensembles. The Particle filters have good results with a relatively high number of samples. In this presentation, we explain the difference between the process of the particle filter and the ensemble Kalman filter algorithm and show the experimental results of the two filters.

REFERENCES

A BAYESIAN DEEP LEARNING FRAMEWORK FOR UNCERTAINTY QUANTIFICATION OF STOCHASTIC PARTIAL DIFFERENTIAL EQUATIONS

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ABSTRACT
Solving stochastic partial differential equations (SPDEs) is a challenging task in uncertainty quantification. Various methods including polynomial chaos has been developed over the past few decades to deal with this problem. However, the computational cost grows exponentially as the dimension increases termed as the curse of dimensionality. To this end we propose a Bayesian deep learning framework to solve high-dimensional SPDEs. Numerical examples are presented to illustrate the efficacy of the proposed method.
Construction of a WENO scheme based on the exponential approximation space enhancing the third-order WENO scheme

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ABSTRACT

The goal of this study is to develop a novel weighted essentially nonoscillatory (WENO) finite difference scheme that improves the ability of the various third-order WENO methods. The approximation space is spanned by exponential polynomials and the shape parameter in the exponential polynomials can be regulated to adjust the local data feature, showing in better results compared to the algebraic polynomial-based schemes. We suggest an explicit form of the shape parameter and one can see that is enables the proposed scheme achieves the improved approximation order (that is, fourth-order accuracy) in smooth regions without loss of accuracy at critical points. Through several well-known benchmark numerical experiments, the our new WENO scheme captures complex shapes better near discontinuities than other third-order WENO schemes.

REFERENCES

DISTINGUISHING NON-TUBERCULOUS MYCOBACTERIA LUNG DISEASE AND TUBERCULOSIS USING DEEP LEARNING

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ABSTRACT

As the development of technologies in classifying non-tuberculous mycobacteria (NTM) lung disease from tuberculosis (TB), the rate of NTM in the entire lung disease increases gradually. However, the same kinds of abnormal lesions in TB and NTM such as atelectasis, cavities, and nodules make it difficult to distinguish between them in the early diagnosis. In this study, we propose a model that can aid the diagnosis of TB and NTM lung diseases by using deep learning techniques on chest X-ray images which is widely utilized. To find the best model, we conduct experiments on several Convolutional neural networks (CNNs) including DenseNet 201, ResNet 50, EfficientNet B4, EfficientNet B5 with or without transfer learning. The model, EfficientNet B4 with transfer learning pre-trained on Noisy Student, is chosen and the optimizer is adopted as Stochastic Gradient Descent (SGD) with a momentum value of 0.9 and the initial learning rate is 0.005. Our model classifies Normal, TB, and NTM lung disease with the highest accuracy 0.92 and the average accuracy 0.87 in 10-fold cross verification. Furthermore, it detects the localization of lesions in existing research levels.
OPTIMAL CONSTANT FOR GENERALIZED DIAGONAL UPDATE METHOD

YOUNG-JIN KIM \(^1\) and JEONG-HOON JU \(^2\)

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ABSTRACT

It is proved that the diagonal update method for the quadratic matrix equation can be used in the Bernoulli’s method and have better results remaining monotone convergence. In this talk, we suggest the optimal constant which guarantees the monotone convergence and extend the sufficient condition to use the diagonal update method. Moreover, we also compare the number of iterations defined by the generalized diagonal update method, the original diagonal update method, and the pure iteration method.

REFERENCES


A Study on the Effects of Isolation and Contact-Tracing Interventions for COVID-19 in South Korea

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ABSTRACT

Recent COVID-19 outbreaks pose serious public health challenges all around the world. South Korea had experienced the early outbreak of the COVID-19 pandemic and implemented effective interventions. The 2020 COVID-19 outbreak in South Korea showed spatial hot spots and superspreading events. As a result of these super-spreading events, three huge outbreaks of the COVID-19 have occurred in Korea from February to December 2020. To capture the intrinsic nature of heterogeneity, an agent-based model has been developed. Based on the social empirical incidence information of confirmed cases of COVID-19, we have constructed a scale-free and small-world network. Our agent-based model has incorporated essential individual variabilities such as different contact numbers and incubation, infectious period, and asymptomatic cases. In the absence of vaccines or treatment, contact tracing and social distancing are the most critical interventions to prevent larger outbreaks. First, we investigate the impact of network structures on key epidemic outputs including incidence, effective reproduction number, degree distribution of secondary cases. Next, we explore the effectiveness of various interventions under two different network structures.

REFERENCES


COMPLEXITY ANALYSIS OF INFEASIBLE PRIMAL-DUAL INTERIOR POINT METHOD FOR SEMIDEFINITE OPTIMIZATION BASED ON THE NEW CLASS OF KERNEL FUNCTIONS.

Jong-Kyu LEE\textsuperscript{1}, You-Young CHO\textsuperscript{2}, Jin-Hee JIN\textsuperscript{3} and Gyeong-Mi CHO\textsuperscript{2}

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ABSTRACT

In this paper, we suggest a new complexity analysis of full Nesterov-Todd step infeasible interior-point algorithm for semidefinite optimization [1]. We define a new class of kernel functions which include a logarithmic kernel function [2] and a trigonometric kernel function [3] and we show that the proposed algorithm have best known complexity $O(n \log(\frac{2}{\epsilon}))$ for semidefinite optimization. The main iteration of the algorithm consists of a few centering steps and a feasibility step. The feasibility step is induced by the newly proposed kernel function, while the centering step is constructed by using of Nesterov-Todd search directions.

REFERENCES

Closed-form pricing formula for foreign equity option with credit risk

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ABSTRACT
Since credit risk in the over-the counter (OTC) market has undoubtedly become very important issue, credit risk have to be considered when the options in the OTC market are priced. In this paper, we consider the valuation of foreign equity option with credit risk. In order to derive a closed-form pricing formula of this option, we adopt the partial differential equation (PDE) approach and use the Mellin transform method to solve the PDE. Specifically, triple Mellin transforms are used, and the pricing formula is presented as 3-dimensional normal cumulative distribution functions. Finally, we verify that our closed-form formula is accurate by comparing it with the numerical result from the Monte-Carlo simulation.
CNN-BASED PREDICTION OF KNEE-POINT IN CAPACITY DEGRADATION OF LI-ION BATTERIES

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ABSTRACT

Lithium-ion batteries are popularly used as power sources in diverse fields due to their many advantages, such as high energy and power density. However, the Li-ion batteries have a problem of decreasing capacity while repeating charging and discharging. The capacity of the batteries decreases slowly initially and then rapidly from the knee-point. Therefore, it is essential to predict the knee-point early for the safe and reliable use of the battery. This study suggests a knee-point prediction algorithm based on Convolutional neural networks, which classified the knee-point with 93.55% accuracy using the initial 3-cycles data and predicted it with an error of 49 cycles using the 50-cycles data.
Effective Gradient Leakage for Model Inversion

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ABSTRACT

Federated learning is a distributed framework for training large machine learning models. Each member receives the current parameter of the network and sends the gradient to update the parameter based on local input data. Previous attacks largely depend on the leakage of the intermediate feature data and overlook the risk of the gradients. However, in this scenario, the gradient leakage could lead to leakage of the data. We show that the input data can be recovered with gradient information and verify that it is the risk depends on the initializing distribution of the parameters.
Singular value decomposition of the attenuated conical Radon transform with a fixed central axis and opening angle

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ABSTRACT

Several types of conical Radon transforms have been studied since the introduction of the Compton camera. Several factors of a cone of integration can be considered as variables, for example, a vertex, a central axis, and an opening angle. In this paper, we study the conical Radon transform with a fixed central axis and opening angle. Furthermore, we consider the attenuation effect in the conical Radon transform because it allows us to obtain a high-quality reconstruction image. We construct a nonseparable Hilbert space and its maximal orthonormal set. This maximal orthonormal set comprises the eigenfunctions of the attenuated conical Radon transform, i.e. singular value decomposition (SVD). Finally, the inversion formula of the attenuated conical Radon transform is deduced from the SVD.

REFERENCES

Universally valid reduction of multiscale stochastic biochemical systems with simple non-elementary propensities

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ABSTRACT

As experimentally characterizing all underlying kinetics of reactions in biochemical systems is almost impossible, their combined effects have frequently been described by simplified non-elementary reaction functions (e.g., Hill and Morrison functions) for over a century. Recently, the deterministically driven non-elementary reaction functions have been heuristically used for stochastic simulations with the Gillespie algorithm. While this approach has been one of the most popular methods for efficient stochastic simulations, its validity condition has remained poorly understood. In this presentation, we derive a complete condition under which this approach can accurately capture the stochastic dynamics of reversible binding, the critical reaction to describe nearly all biochemical systems such as gene regulation and enzyme-catalysis. Furthermore, we develop alternative simplified reaction functions for stochastic reversible binding. This provides a universally valid framework for the simplification of stochastic biochemical systems with rapid reversible bindings.
Data Assimilation : real-time forecasting
Hand-Foot-and-Mouth Disease(HFMD)

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ABSTRACT

Predicting in real time before the epidemic spreads are very important in modern society. A technique called data assimilation has been mainly used for real-time prediction using data such as weather prediction and ocean physics reception. In general, we try to estimate the reality of the phenomenon through a process model that describes this particular phenomenon, and through measurements directly observing that phenomenon. Nowadays, real-time prediction models using data assimilation are used in various fields. The reason why data assimilation is used in the epidemic prediction model is that realistic epidemic prediction is possible using a combination of process models and measurements.

In this research, we establish an experimental predictive model by exemplifying the hand, foot and mouth disease, which spreads widely and periodically among infectious diseases in summer. HFMD is a viral disease and is one of the most prevalent diseases among children and requires a predictive model. Therefore, we develop, compare and analyze a real-time prediction model using two of the data assimilation methods, EnKF(Ensemble Kalman Filter) and PF(Particle filter).

REFERENCES

Composition-Aware Image Steganography through Adversarial Self-Generated Supervision

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ABSTRACT

Steganography is an important and prevailing information hiding tool to perform secret message transmission in an open environment. Existing steganography methods can mainly fall into two categories: pre-defined rule-based and data driven methods. The former is susceptible to the statistical attack while the latter adopts the deep convolution neural networks to promote security under statistical attack. However, the deep learning-based methods suffer from perceptible artificial artifacts. In this paper, we introduce a novel Composition-Aware Image Steganography termed CAIS to guarantee both visual security and robustness to attack through self-generated supervision. The key innovation is an adversarial composition estimation module to integrate rule based and deep generative adversarial methods. We perform a rule-based image blending method to obtain infinite synthetically data-label pairs and perform an auxiliary adversarial composition estimation task. The innovative self-generated supervision could largely promote the ability to recognize message patterns from steganographic outputs, which results in better steganography performance. Furthermore, an effective Global-and-Part checking is designed to alleviate visual artifacts caused by hiding secret information. We conduct a comprehensive analysis of CAIS from various aspects such as security and robustness to verify the superior performance of the proposal. Experimental results on three large scale widely-used datasets show the superior performance of our CAIS compared with several state-of-the-art approaches.

EQUATIONS, TABLES AND FIGURES

Some important framework and experimental results table are listed as following:
Figure 1. Alice intends to send her portrait to Bob by transmitting it in an open community while she does not want anyone other than Bob access to her photo. So Alice randomly selects a cover image and hides the message image (her portrait) to generate a steganographic image, which is visually identical to the cover image. Even this steganographic image is intercepted by a third party like Eve, no personal information of Alice will be recognized.

Figure 2. The four components of the full system. Upper Left Corner: Hiding message image $x_m$ in cover image $x_c$ through steganography function $F$ and synthesizing steganographic output $\tilde{x}_c$. Lower left corner: Generating composite image $x_w$ by Alpha blending and using self-generated data-label: $(x_w, \alpha)$ to optimize the auxiliary estimator of $D_p$. Lower Right Corner: Randomly cropping part regions from $x_c$ and $\tilde{x}_c$ and performing part checking through part discriminator $D_p$. Upper Right Corner: Uncovering the steganographic image with the revealing network $G$ to a reconstructed image $\hat{x}_m$.

REFERENCES


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Table 1 Quantitative comparison of **Within-domain image steganography** between different methods. ↑ (↓) indicates that the larger (smaller) the value is, the better the performance.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Steganography</th>
<th>Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MSE ↓</td>
<td>RMSE ↓</td>
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<tr>
<td>Steganography [3]</td>
<td>0.0022</td>
<td>0.0462</td>
</tr>
<tr>
<td>Deep-stegano [49]</td>
<td>0.0015</td>
<td>0.0370</td>
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<tr>
<td>ISGAN [67]</td>
<td>0.0014</td>
<td>0.0395</td>
</tr>
<tr>
<td>CAIS</td>
<td>0.0011</td>
<td>0.0297</td>
</tr>
</tbody>
</table>

Figure 3. The visual within-domain image steganography comparison of different methods. The images at the left side of black dotted show the steganography comparison while the images at the right side of black dotted show the reconstruction comparison.


7. Mathilde Caron, Piotr Bojanowski, Armand Joulin, and Matthijs Douze. Deep clustering
Table 2: Quantitative comparison of Cross-domain image steganography between different methods. ↑ (↓) indicates that the larger (smaller) the value is, the better the performance.

<table>
<thead>
<tr>
<th>Methods</th>
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<th>Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Steganography [3]</td>
<td>0.0027</td>
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<td>Deep-stegano [49]</td>
<td>0.0025</td>
<td>0.0497</td>
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<tr>
<td>ISGAN [67]</td>
<td>0.0014</td>
<td>0.0384</td>
</tr>
<tr>
<td>CAIS</td>
<td><strong>0.0010</strong></td>
<td><strong>0.0151</strong></td>
</tr>
</tbody>
</table>

Figure 4. The visual cross-domain image steganography results of different methods. The images at the left side of black dotted show the steganography comparison while the images at the right side of black dotted show the reconstruction comparison.


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Information Maximizing Generative Adversarial Networks for Capacity Estimation Using Impedance of Lithium-Ion Batteries

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ABSTRACT

This study proposes the use of information maximizing generative adversarial networks for the reliable extraction of latent variables representing the characteristics of lithium-ion batteries (LIBs) from electrochemical impedance spectroscopy (EIS) data in a fully unsupervised manner. Meaningful representations were obtained from EIS data measured with direct current and without relaxation, which are difficult to analyze when using equivalent circuit models. The extracted latent variables were investigated as capacity degradation progressed and were used to estimate the discharge capacity of the batteries using Gaussian process regression. We demonstrate that the extracted latent variables from EIS data measured with direct current and without relaxation reliably represent the degradation characteristics of LIBs.
Novel methods for effective household object classification using depth images

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ABSTRACT

In this thesis, we propose a novel model with high classification performance using an additional structure called non-local block. Object recognition field that utilizes depth images is one of the key technologies in robotics and autonomous driving fields. Therefore, this thesis suggest a much improved model using not only RGB information but also depth information. In order to use the depth features well, we improve the classification accuracy by using a non-local block, one of the types of attention structures.

REFERENCES

References are to be listed at the end of the paper in the order of the reference, and are referred to in the paper by the numbers in brackets such as [?,?]. Style the reference list according to the following examples.

(1) Paper in a journal

(2) Paper in Conference Proceedings

REFERENCES


Mathematical Modeling and Numerical Simulation of Lithium-Ion Batteries

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ABSTRACT

Due to its high energy density and power density, lithium-ion battery (LIB) is one of the commonly used batteries for electric vehicles (EVs). Many researches have been conducted based on empirical models to take advantage of their simplicity and computational low cost. Nevertheless, physics-based researches are necessary to monitor internal state of a battery and to simulate the battery in different conditions. The Pseudo-two-Dimensional (P2D) model introduced by Doyle and Newman is a well known electrochemical model. We demonstrate that the computational cost of the P2D model can be reduced by using the Taylor series expansion for nonlinear terms and using an adaptive time-stepping method which determines the time step size in accordance with the residual of the cell voltage. Simulation results were verified by comparing them with the results from previously developed toolbox, LIONSIMBA, as a benchmark.
PARTICLE FILTERING FOR STOCHASTIC CESSI-YOUNG EQUATION
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ABSTRACT

Particle filtering methods can be applied to nonlinear, non-Gaussian systems. Its advantage is that it does not need to assume any form of the prior probability density function of the model state, but instead uses the full prior probability density. The stochastic Cessio-Young equation is a conceptual model of climate-mean ocean thermohaline circulation proposed by Eyink in 2005. In this paper, the particle filter method is applied to the stochastic Cessio-Young equation to estimate the model state, evaluate the filter performance, and compare the results with the ensemble Kalman filter.

REFERENCES

(1) Book

(2) Paper in a journal


Applications of the Particle Filter to the Double-Well Potential Model (DWPM)

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ABSTRACT

The particle filter was invented as a numerical approximation to a nonlinear Bayesian filtering problem. Today, there is enough theory and several successful applications described in the literature. In this presentation, we review the particle filter in application to a dynamic model with highly non-Gaussian statistics using a numerical discretization of the Fokker-Planck equation to evolve the system statistics. The model that we apply is a nonlinear stochastic diffusion process in a double-well potential. The optimal convergent filtering schemes that we use in the estimation are a standard convergent particle method, which is commonly known as the Weight Resampling Filter.

REFERENCES

Efficient training of pricing networks using Greeks

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ABSTRACT

The Black-Scholes model is still very popular for option pricing because of its simplicity and existence of the closed formula. However, the model cannot reflect the leverage effect since the assumption of the model is that volatility is constant. To solve this problem, many models have been developed such as CEV, Heston, SABR, etc. But they are computationally expensive since they do not have an analytic closed solution. According to Huh et al. (2021), the computational cost can be significantly reduced utilizing the neural network. [1]

In this study, we trained two types of neural networks to predict the option prices for the Black-Scholes and SABR models, respectively, where the one is obtained using the values only, while the other is obtained using the values and Greeks together. First, we compared the two neural networks for the Black-Scholes model with the well-known closed formula. As a result, the neural network using Greeks achieved much higher accuracy. Next, we compared two neural networks for the SABR model which has no closed formula. Since the Black-Scholes model has the closed formula, there is not any difficulty to generate the Greeks, but the SABR model is not. Therefore, we generate a large number of prices for the SABR model using Monte-Carlo simulation and calculate Greeks using adjoint automatic differentiation (AAD). Same as the previous result, the networks using the Greeks outperformed the other type of network using the values only. Hence, these test results show that the training of the pricing networks considering not only the values but also Greeks can induce an efficient formula regardless of the existence of an analytic closed formula.

REFERENCES


DEVELOPMENT OF A MATHEMATICAL MODEL FOR PREDICTING ACCURATE HEPATIC CLEARANCE OF DRUG

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ABSTRACT

Clearance (CL), the amounts of a drug metabolized by enzymes per unit time, is the major pharmacokinetic measurement used in the development and determination of the dosage of medications. In vivo hepatic CL of a drug has been predicted by extrapolating in vitro intrinsic CL whose estimation is based on the Michaelis-Menten (MM) equation, which is the result of the standard quasi-steady-state approximation (QSSA). However, in vivo drug CL predicted in that way becomes inaccurate if in vivo hepatic enzyme concentration is not sufficiently lower than the MM constant of the drug. Here, we develop an alternative approach based on the total QSSA, which accurately predicts in vivo CL of drugs regardless of their MM constant values.
Designing optimizing procedures for task switching to ensure efficiency in the hospital laboratory

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2) Institut für Mathematik, Technische Universität Berlin, Berlin, Germany
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ABSTRACT

This study aims to improve the efficiency of task switching in hospital laboratories. In a laboratory, several medical technicians perform multiple tasks. Technicians are not aware of the marginal amount of time it takes to switch between tasks, and this accumulation of lost minutes can cause the technician to worry more about the remaining working time than work quality. They rush through their remaining tasks, thereby rendering their work less efficient. For time optimization, we identified work changeover times to help maintain the work quality in the laboratory while reducing the number of task switching instances. We used the turnaround time (TAT) compliance rate of emergency room samples as an indicator to evaluate laboratory performance and the number of task switching instances as an index of the task performer perspective (TPP). We experimented with a monitoring system that populates the time for sample classification according to the optimal time for task switching. Through the proposed methodology, we successfully reduced not only the instances of task switching by 10% but also the TAT non-compliance rate from 4.97% to 2.66%. Consequently, the introduction of new methodology has greatly increased work efficiency.

REFERENCES

SENSITIVITY AND STABILITY ANALYSIS OF AN EBOLA VIRUS DISEASE AND GBV VIRUS CO-INFECTION
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ABSTRACT

In this work, we propose a nonlinear mathematical model to study the transmission dynamics of the Ebola Virus Disease (EVD) and the Hepatitis G virus (GBV) co-infection. The basic reproductive number is found by the next-generation matrix method. Then the infectious free and endemic equilibrium of the system is computed. The local and global stability of the system is presented as well. For local asymptotical stability, linearization, and Routh-Hurwitz criterion and show that if \( R_0 < 1 \), then the system is locally asymptotically stable otherwise unstable. The global asymptotical stability is found out by the Lyapunov function method. Finally, we present a numerical simulation of the proposed model.

REFERENCES


THE PRICING OF VULNERABLE POWER OPTIONS
WITH DOUBLE MELLIN TRANSFORMS

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ABSTRACT

In the modern financial market, the scale of financial instrument transactions in the over-the-counter (OTC) market are increasing. However, in this market, there exists a counterparty credit risk. Herein, we obtain a closed-form solution of power option with credit risks, using the double Mellin transforms. We also use a numerical method to compare the differentiations of option price between the closed-form solution and Monte-Carlo simulation. The result shows that the closed-form solution is precise. In addition, the option’s price is sensitive to the exponent of the maturity stock price.

REFERENCES


EFFICIENT IMMERSED BOUNDARY PROJECTION METHOD FOR HEAT TRANSFER PROBLEMS

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ABSTRACT

An efficient immersed boundary projection method (IBPM) with staggered time discretization (STD) is proposed for incompressible viscous flow with heat transfers. The main idea is to use a block LU decomposition technique for the momentum and the energy equations. The pressure, the momentum, and the energy forces are treated as Lagrangian multipliers to impose the divergence-free constraints and no-slip conditions at the IB surface. A staggered time discretization with Crank-Nicolson scheme is applied to decouple the momentum and the energy equations, which means that the velocity fields are described at integer time levels \((n+1)\), while the temperature fields are described at half-integer time levels \((n + 1/2)\). Thus, we obtain an efficient immersed boundary projection method with a staggered time discretization. Numerical simulations of two-dimensional (2D) forced and natural convection problems are performed to demonstrate the validity of the present method. All the results show satisfactory agreements with the results obtained by the body-fitted approach.
Spatial-temporal patterns of COVID-19 using dynamic mode decomposition

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ABSTRACT

The worldwide spread of Coronavirus disease-2019 (COVID-19) in 2020 has posed serious public health problems to all around the world. In this work, we develop a fast, computationally inexpensive, high-fidelity mathematical model using a data driven approach, Dynamic Mode Decomposition (DMD). DMD is a dimensionality reduction method that analyzes spatial-temporal patterns of COVID-19 transmission dynamics in South Korea. The novelty of our work is that given several time series data sets, we divide the data sets in several time periods so that the window-wise data sets are consistent. We then apply the DMD for each consistent data set, leading to a meaningful dynamic mode analysis.

REFERENCES

4D-VAR METHOD WITH LORENZ 63 MODEL

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ABSTRACT

Modern society faces serious climate problems caused by industrialization and environmental pollution. As the abnormal climate problem becomes more serious, the importance of predicting and preparing for it is emerging. Data assimilation (DA) is a technique that plays an important role in improving the accuracy of predictions, and reduces the error of predictions using observational data. This poster shows the prediction process of 4D-Var, which uses Variational method among data assimilation techniques. The model is one of the atmospheric models which is commonly called the Lorenz 63 model and uses the twin data assimilation experiment to make a true state and data.

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WEB-BASED DIAGNOSTIC PERFORMANCE COMPARISON OF MOBILE PHONE AND COMPUTER THROUGH CNN IN DIAGNOSING THYROID NODULE ON ULTRASONOGRAPHY

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Corresponding Author: Beomgi So, beomgi0613@yonsei.ac.kr

ABSTRACT

Thyroid nodule is a common disease and according to static from the National Cancer Information Center, it occurred at 26,1760 per 100,000 Koreans as of 2017. With recently advances in computers, Convolution Neural Network(CNN) is great help in diagnosing thyroid nodules. This study develop an algorithm to diagnose malignant thyroid nodule using CNN’s transfer learning technology. To train ultrasound images of thyroid nodules with CNN, 13,560 thyroid images collected at Severance Hospital from 2004 to 2019 were used. In order to make the CNN algorithm user-friendly, a web application is created by building a medical server. This study was conducted on confirmed on among 259 patients who were confirmed through Fine Needle Aspiration(FNA) from December 2019 to October 2020 at Severance Hospital. As a result, the AUC values are respectively 0.896 and 0.875 when using PC and mobile. This AUC values similar to those of experienced radiologists. Therefore, It can be fully referenced as secondary information. Moreover, The web application can be easily accessed internet environment. Users could use this web application in internet environment.

REFERENCES

Benefits of the reward system in text generation

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ABSTRACT

Generative Pre-trained Transformer 2 (GPT-2) is one of the powerful language models, which records high scores in various Natural Language Processing (NLP) tasks. Especially in the text generation field, it performs like a human for writing novels and news. We introduce a GPT-2 based text generation algorithm, which by adding an optimization process using the Reinforcement Learning (RL) algorithm, Proxy policy optimization (PPO), and show that the reward system in RL can contribute to NLP and generative models for text.

REFERENCES

Data-based inference method reveals the network structure of the circadian clock

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ABSTRACT

The suprachiasmatic nucleus (SCN) is the central circadian pacemaker in mammals. Even though the SCN is composed of thousands of heterogeneous self-oscillating cells, the SCN can synchronize its component oscillators through the SCN neuronal network. To understand the SCN network structure, previous methods used the time series data to infer the network structure. However, because the SCN is synchronized, previous methods falsely inferred the network as if all the SCN cells were coupled with each other. To circumvent this, we develop a novel data-based method, which can successfully infer the SCN network from the time series data. In particular, our method accurately infers the SCN network with single-cell resolution bioluminescence data from 2,000 synchronized mice SCN cells. Furthermore, our method can infer the directionality of the coupling between SCN cells.
Blood Flow in Catheterized Artery: Numerical Study

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ABSTRACT

The evolution of coronary balloon angioplasty has increased the use of various sizes catheters in the arteries during the recent years. In the present study, pulsatile blood flow through catheterized artery is analyzed by the flow modelling of two immiscible fluids. The fluid flow in the primary region is treated as non-Newtonian power law fluid while, the fluid flow in peripheral region is categorized as Newtonian fluid. The catheter inside the vessel is treated as rigid body of small radius. The resulting system of differential equations that represents the velocity profiles of the respective fluids are solved numerically by finite difference method. Additionally, the results of velocity profiles with different physical quantities are analyzed by numerical method and ANSYS-Fluent simulations for the purposes of a comprehensive summary of blood flow through catheterized artery.

References:

The effect of the awareness and treatment on HIV spread in developing and developed countries

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ABSTRACT

In this study, we analyze a mathematical epidemic model and check the status of HIV in the USA and Pakistan. We estimated some parameters by using the maximum likelihood method and fitted the model with recent data in both countries. With this estimation, we observe that the basic reproduction number in the USA is 0.9688, while our estimation for Pakistan for the basic reproduction number is 2.2599. In the case of the USA, with this reproduction rate disease will die out but it would take a long time to eradicate this disease completely. Meanwhile, in Pakistan, due to a lack of awareness in the confirmed group and a lower rate of maintained treatment, this reproduction number is very high. For both countries, we estimated the rate of vertical transmission, which plays a significant role in Pakistan but not in the USA. We noticed that improving the screening and treatment rate with educating people would be effective for controlling HIV in Pakistan, whereas an improved screening rate in the USA can eradicate HIV faster.

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PARTICLE TRACING USING LTRANS

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ABSTRACT

The Lagrangian TRANSPORT model (LTRANS) is a particle-tracking model that runs with the predictions of a 3D hydrodynamic model, specifically the Regional Ocean Modeling System (ROMS). Particles refer to oil droplets or marine organisms like fish eggs or larvae that do not have swimming ability and are mostly transported by currents. In this pilot study, about 1400 particles are released in the South Sea of Korea and are tracked during the simulated time. We estimate the dispersal and connectivity (from source to sink) of the particles.

![Figure 1. Particles tracking](image)

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Personalized sleep-wake patterns aligned with circadian rhythm relieve daytime sleepiness

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ABSTRACT

Shift workers and many other groups experience irregular sleep-wake patterns. This can induce excessive daytime sleepiness that decreases productivity and elevates the risk of accidents. However, the degree of daytime sleepiness is not correlated with standard sleep parameters like total sleep time, suggesting other factors are involved. Here, we analyze real-world sleep-wake patterns of shift workers measured by wearables with a newly developed user-friendly computational package that simulates homeostatic sleep pressure – the physiological need for sleep – and the circadian rhythm. This reveals that shift workers who align sleep-wake patterns with their circadian rhythm have lower daytime sleepiness, even if they sleep less. The alignment, quantified by a new parameter, circadian sleep sufficiency, can be increased by dynamically adjusting daily sleep durations according to varying bedtimes. Our computational package provides flexible and personalized real-time sleep-wake patterns for individuals to reduce their daytime sleepiness and could be used with wearable devices to develop smart alarms.
Korean Document Clustering by Topic Using Matrix Factorizations

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ABSTRACT

In this study, we propose a document clustering algorithm for pre-trained topic modeling using CUR decomposition, one of the matrix factorizations. This algorithm considers the characteristics of agglutinating words of Korean, various fusions of morphemes, and morphological ambiguity. Experiments are provided based on unclassified Korean Wikipedia document data and Newspaper corpus 2020. We will compare accuracy of latent semantic analysis (LSA) using CUR decomposition and classical singular value decomposition (SVD), respectively.

REFERENCES


Effect on tumor growth in systems of two different types of tumor-associated neutrophils: A mathematical model

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ABSTRACT

Until recently, the role of tumor-associated neutrophils (TANs) as members of the complex tumor microenvironment has long been ignored due to technical difficulties in tumor biology, furthermore, the role of TANs is controversial because both tumor-promoting and tumor-suppressing effects have been reported. But these neutrophils are emerging as important agents in tumor invasion and metastatic regulation. In this study, we divided into two components depending on the role of TANs: (i) the antitumorigenic neutrophils, called N1 TANs (ii) the tumorigenic neutrophils, called N2 TANs. TGF-beta has been identified as a major cytokine in the tumor microenvironment that induce N2-dominant state and IFN-beta in the tumor microenvironment was shown that enhance N1 TANs and can suppress tumor growth by interacting p53. We developed a mathematical model to investigate the dynamics of tumor growth between tumor suppressive N1 TANs and tumor promoting N2 TANs. The model predicts the dynamics between N1 TANs and N2 TANs in response to various TGF-beta and IFN-beta stimuli. In addition, we investigated how N1 and N2 influence tumor growth depending on who dominates.

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Understanding and Optimal Ensemble Size of Ensemble Kalman Filter via Lorenz Model.

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ABSTRACT

An optimal estimation deduces a minimum error estimation value to the system state. The purpose of this study is to understand the ensemble Kalman filter, and apply it to the Lorenz model.

EnKF was developed by Evensen in 1994 to handle strongly non-linear models. and it can be seen as a Monte Carlo approximate version of the Kalman filter. EnKF uses a random sample called an ensemble to represent the distribution of the system and uses a sample covariance matrix calculated by the ensemble to predict and update the ensemble state.

We perform two experiment. Experiment 1 compares the result of the ensemble Kalman filter with reference solution maded by Runge-Kutta 4th. Second, experiment 2 compared the accuracy and cost of ensemble Kalman filters according to the number of ensemble size.

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