2023 年度 研究助成 対象者

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法政大学 情報科学部
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【研究テーマ】
超大規模行列のための深層展開手法の確立

（23-01）

Hosei University
Professor

Katsumi Konishi

Deep Unfolding for Huge Low-Rank Matrix Completion

P.8

通信・インターネット分野　Communications / Internet

東京大学 生産技術研究所
特任助教　**小島　駿**

【研究テーマ】
可視光通信系における物理層セキュリティ基盤の構築

（23-02）

The University of Tokyo
Project Research Associate

Shun Kojima

Development of Physical Layer Security for Visible Light Communications

P.10

京都大学 大学院 情報学研究科
助教　**白木　隆太**

【研究テーマ】
光ファイバ通信網の大容量化を実現するディジタル信号処理技術

（23-03）

Kyoto University
Assistant Professor

Ryuta Shiraki

Digital Signal Processing Enabling Large-Capacity Photonic Networks

P.12

大阪大学 大学院 工学研究科
助教　**久野　大介**

【研究テーマ】
映像無線伝送を目的とした情報源ー通信路結合符号化方式に関する研究

（23-04）

The University of Osaka
Assistant Professor

Daisuke Hisano

Deep Joint Source-Channel Coding for Wireless Video Transmission

P.14

大阪大学 大学院 工学研究科
准教授　**三科　健**

【研究テーマ】
超低遅延・大容量光ネットワークのための全光信号処理技術に関する研究

（23-05）

The University of Osaka
Associate Professor

Ken Mishina

Study on All-Optical Signal Processing for Ultra-Low-Latency and High-Capacity Optical Networks

P.16

人工知能分野　Artificial intelligence

産業技術総合研究所 マルチマテリアル研究部門
主任研究員　**島本　太介**

【研究テーマ】
データ駆動型材料開発に資する外挿と説明が可能な数学モデルを見出す AI に関する研究

（23-06）

National Institute of Advanced Industrial Science and Technology
Senior Research Scientist

Daisuke Shimamoto

Research on AI to Generate the Extrapolation and Explainable Mathematical Models Leading to the Development of Data-Driven Materials

P.18

人工知能分野　Artificial intelligence

東京大学 大学院 情報理工学系研究科
助教　**中川　聡**

【研究テーマ】
ユーザの包括的な状態理解に基づきQOL向上に導く対話システムの開発

（23-07）

The University of Tokyo
Assistant Professor

Satoshi Nakagawa

Development of a Dialogue System Guiding QOL Improvement Based on Comprehensive User Understanding

P.20

バイオ分野　Bioinformatics

東京大学 大学院 工学系研究科
助教　**林　勇佑**

【研究テーマ】
*in silico*シミュレーションを用いた凍結保護剤設計基盤

（23-08）

The University of Tokyo
Assistant Professor

Yusuke Hayashi

Design Platform of Cryoprotective Agents with *in silico* Simulation

P.22

応用分野（A）　Applications (A)

東京農工大学 大学院 工学研究院
教授　**藤波　香織**

【研究テーマ】
異種センサ統合と能動学習による組立作業時の高精度な迷い推定

（23-09）

Tokyo University of Agriculture and Technology
Professor

Kaori Fujinami

Confusion Recognition in Assembly Tasks Based on Multi-Modal Sensor Fusion and Active Learning

P.24

応用分野（B）　Applications (B)

旭川医科大学 内科学講座
助教　**安藤　勝祥**

【研究テーマ】
新規画像補正技術と機械学習・深層学習を用いた潰瘍性大腸炎の自動診断システムの開発

（23-10）

Asahikawa Medical University
Assistant Professor

Katsuyoshi Ando

Development of an AI-Based Ulcerative Colitis Diagnosis System Using Advanced Image Correction and Deep Learning

P.26

岡山大学 学術研究院 環境生命自然科学学域
教授　**岡安　光博**

【研究テーマ】
磁界及び情報通信技術を用いた駅プラットホームにおける視覚障害者用バリアフリーシステムの開発

（23-11）

Okayama University
Professor

Mitsuhiro Okayasu

Development on Barrier Free System Using Magnetic Fields and Information and Communication Technology for Blind People on Station Platform

P.28

福井大学 大学院 工学研究科
准教授　**川上　朋也**

【研究テーマ】
テレマティクスデータを活用した運転者特性に基づく安全経路推薦システムの構築

（23-12）

University of Fukui
Associate Professor

Tomoya Kawakami

Construction of a Safe Route Recommendation System Based on Driver Characteristics Utilizing Telematics Data

P.30

応用分野（B） Applications (B)

慶應義塾大学 医学部
特任講師 **清水 映輔**

【研究テーマ】
情報・通信技術の応用：途上国・医療過疎地でも眼科診療を可能とするスマホ眼科医療機器を用いた、新しい眼科診療の開発と実用化 （23-13）

Keio University
Project Assistant Professor
Eisuke Shimizu
Application of Information and Communication Technology: Development and Implementation of a Novel Ophthalmic Care Model Using Smartphone-Based Devices to Enable Eye Care in Low-Resource and Medically Underserved Settings
P.32

九州大学 大学院 総合理工学研究院
教授 **谷本 潤**

【研究テーマ】
アフターコロナにおけるパンデミックを阻止するIoTデバイスを通じた予防接種オファーに基づく新興感染症のダイナミック制御 （23-14）

Kyushu University
Professor
Jun Tanimoto
Dynamic Control for Avoiding Pandemic of New-Emerging Epidemic by Social Information System to Offer Vaccination through IoT Devices in After-Corona Era
P.34

人文・社会分野 Humanities and social sciences

山梨大学 大学院 総合研究部 教育学域
准教授 **小野田 亮介**

【研究テーマ】
誤情報拡散における責任感の成立機序に関する研究 （23-15）

University of Yamanashi
Associate Professor
Ryosuke Onoda
Psychological Mechanisms of Responsibility in the Diffusion of Misinformation
P.36

立命館大学 総合心理学部
准教授 **竇 雪**

【研究テーマ】
ネット上の他者の反応が偽情報・誤情報訂正記事の効果に与える影響について （23-16）

Ritsumeikan University
Associate Professor
Xue Dou
Impact of Others' Reactions on Accessing the Credibility of News for Correcting Misinformation
P.38

筑波大学 人文社会系
教授 **星野 豊**

【研究テーマ】
民事訴訟のIT化に伴う訴訟記録管理における情報保護に関する研究 （23-17）

University of Tsukuba
Professor
Yutaka Hoshino
Research on Information Protection in Lawsuit Record Management Associated with the Use of IT in Civil Lawsuits
P.40

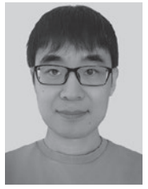
米国 USA（7 件）

University of California, Berkeley
College of Computing, Data Science and Society
Assistant Professor
Natacha Crooks
Towards Scalable Decentralized Databases
P.42

Stanford University
Departments of Computer Science and Electrical Engineering
Assistant Professor
Chelsea Finn
Generality and Dexterity in Visuomotor Control
P.43

University of California, Los Angeles
Computer Science Department
Associate Professor
Nanyun Peng
Detecting and Reducing Hallucination of Generative Language Models
P.44

University of Southern California
Department of Computer Science
Associate Professor
Xiang Ren
Building NLP Systems with Generality and Common Sense
P.45



University of Southern California
Ming Hsieh Department of Electrical and Computer Engineering
Associate Professor
Feng Qian
Towards Robust Video Streaming over Next Generation Mobile Networks
P.46

California Institute of Technology
Division of Biology and Biological Engineering
Professor
Joseph Parker
Evolving Stability in a Multispecies Network
P.47

Carnegie Mellon University
Language Technologies Institute
Assistant Professor
Daniel Fried
Pragmatic Language Interfaces:Modeling Human Users of Natural Language Processing System
P.48

中国 China（4 件）

Peking University（北京大学）
School of Computer Science
Associate Professor

Shiliang Zhang（张史梁）

Fine-Grained Visual Perception in the Wild

P.49

Tsinghua University（清華大学）
Institute for Network Sciences and Cyberspace
Associate Professor

Chao Zhang（张超）

Data-Driven Software Security Analysis

P.50

Fudan University（復旦大学）
School of Information Science and Technology
Associate Professor

Yan Wang（王岩）

Theory and Design of Low-Cost Compact Millimeter-Wave Phased Array Antenna for Mobile Phones

P.51

Shanghai Jiao Tong University（上海交通大学）
Department of Electronic Engineering
Associate Professor

Jian Pang（庞健）

Research on Area- and Power-Efficient Silicon-Based Millimeter-Wave Phased-Array Transceivers Targeting Over 100Gbps

P.52

韓国 Korea（3 件）

Seoul National University（ソウル大学）
Department of Computer Science and Engineering
Professor

Jinwook Seo（徐鎭旭）

Interactive Cluster Examination in Multidimensional Views Using Distortion-Conscious Brushing

P.53

Korea University（高麗大学）
Department of Computer Science and Engineering
Professor

Won-Ki Jeong（鄭元基）

Histopathology Image Analysis Using Incomplete and Weak Labels

P.54

Yonsei University（延世大学）
Department of Computer Science
Assistant Professor

Dokyung Song（宋度炅）

Democratizing Confidential Computing at the Edge through Security-Preserving Optimizations

P.55

超大規模行列のための深層展開手法の確立

小西　克巳
法政大学 情報科学部 教授

1．はじめに

本研究では、超大規模行列のための深層展開手法を扱う。深層展開とは、最適化問題の解法である最急降下法や固定点アルゴリズムなどの繰り返し計算アルゴリズムに対し、深層学習の計算アーキテクチャを利用してアルゴリズム内部の最適なパラメータを与える手法である。通常の繰り返しアルゴリズムでは、内部パラメータはステップ数（繰り返し数）に依らない定数を用いるが、深層展開ではステップ毎に異なる内部パラメータを与えることで、通常の繰り返しアルゴリズムよりも収束速度と解の精度が飛躍的に向上する。多くの数値実験により、深層展開を使わない場合に比べて、数倍〜数十倍に高速化することが示されている。しかしながら、深層展開手法では、全てのステップにおける設計変数の値をメモリに保持しなければならず、超大規模行列や大規模テンソルを計算対象とした場合に、メモリ不足のために深層展開が適用できないという問題がある。そこで本研究では、超大規模行列を対象とする深層展開手法を導出する。

2．提案手法と結果

本研究では、行列因子分解に基づく低ランク行列補完手法に対して深層展開を適用した。具体的には、以下の最適化問題：

$$\min g(U,V)=\sum_{(i,j)\in\Omega}\left\|X^*_{i,j}-U_{i,:}V_{:,j}\right\|_F^2+\lambda(\|U\|_F^2+\|V\|_F^2)$$

を以下を収束するまで繰り返しアルゴリズムで解く手法である。

$$\begin{cases}U_{k+1}\leftarrow U_k-\mu_k\dfrac{\partial g(U_k,V_k)}{\partial U}\\ V_{k+1}\leftarrow V_k-\tau_k\dfrac{\partial g(U_k,V_k)}{\partial V}\end{cases}\qquad(1)$$

ここで、μ_kとτ_kがパラメータであり、これらの値にアルゴリズムの精度と収束精度が依存する。図１は、μ_kとτ_kを固定値とした場合の値による解の精度を可視化したものである。紺色（暗い色）が精度の低い解で黄色（明るい色）が精度の高い解を表し、白色はアルゴリズムが発散して解が得られなかった場合を表す。解の精度がμ_kとτ_kの値に対して大きく依存していることが分かる。本研究では、小規模行列に対して深層展開を適用し、得られたパラメータを超大規模行列に用いる手法を提案した。

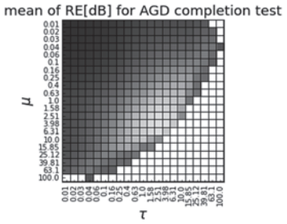


図１．パラメータによる解の精度

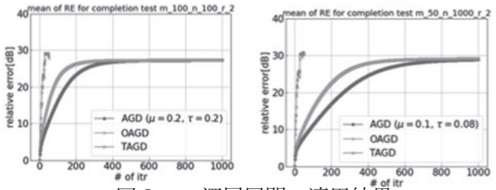


図２．　深層展開の適用結果

式(1)のアルゴリズムに対し深層展開を適用した結果を図２に示す。左図は 100×100 の行列に適用した結果、右図は同じパラメータを 10000×10000 の行列に適用した結果で、横軸が繰り返し数、縦軸が解の相対誤差（dB）を表し、値が大きいほど精度が高い。青が最適な固定パラメータ、オレンジが我々がすでに提案している可変パラメータ、緑が深層展開によるパラメータを利用した結果である。深層展開手法が効果的であることが確認できる。

3．まとめ

本研究では、小規模行列に対して深層展開を適用し得られたパラメータを超大規模行列に用いることで、繰り返しアルゴリズムの高速化および高精度化を行う手法を提案した。数値実験により、有効性が確認された。

Deep Unfolding for Huge Low-Rank Matrix Completion

Katsumi Konishi
Professor, Hosei University

1. Introduction

This study investigates deep unfolding methods for large-scale low-rank matrix completion. Deep unfolding is a computational approach that leverages the architectural principles of deep learning to optimize the internal parameters of iterative algorithms, such as the steepest descent method and fixed-point algorithms, which are commonly used for solving optimization problems. In conventional iterative algorithms, the internal parameters remain constant regardless of the number of iterations. In contrast, deep unfolding assigns distinct internal parameters at each iteration, significantly enhancing both convergence speed and solution accuracy compared to traditional iterative methods. Numerous numerical experiments have demonstrated that deep unfolding can accelerate convergence by a factor of several times to several tens compared to methods without unfolding. However, a major drawback of deep unfolding is its high memory requirement, as it necessitates storing the design variable values for all iterations. This limitation renders deep unfolding impractical when dealing with extremely large matrices or high-dimensional tensors due to insufficient memory capacity. To address this issue, this study proposes a deep unfolding method specifically designed for very large-scale matrices.

2. Main Results

In this study, we applied deep expansion to a low-rank matrix completion method based on matrix factorization, which is formulated as the following optimization,

$$\min g(U,V)=\sum_{(i,j)\in\Omega}\left\|X^*_{i,j}-U_{i,:}V_{:,j}\right\|_F^2+\lambda(\|U\|_F^2+\|V\|_F^2)$$

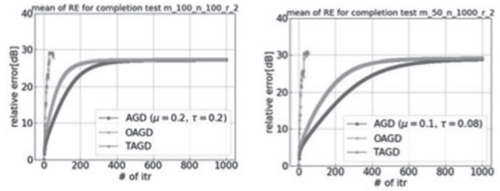


Figure 1:　results of deep unfolding

where μ_k and τ_k are parameters. The accuracy of the algorithm depends on these parameters. In this study, we propose a method in which deep unfolding is applied to small-scale matrices to obtain optimal parameters, which are then utilized for solving very large-scale matrices.

Figure 1 presents the results of applying deep unfolding to the algorithm in Equation (1). The left panel shows the results for a 100×100 matrix, while the right panel depicts the performance when the same parameters are applied to a 10,000×10,000 matrix. The horizontal axis represents the number of iterations, whereas the vertical axis shows the relative error (dB) of the solution, with larger values indicating higher accuracy. The blue line corresponds to the optimal fixed parameters, the orange line represents the previously proposed variable parameters, and the green line indicates the results obtained using parameters derived from deep unfolding. These results confirm the effectiveness of the deep unfolding approach.

3. Conclusion

In this study, we proposed a method to accelerate and enhance the accuracy of iterative algorithms by applying parameters obtained from deep unfolding on small-scale matrices to very large-scale matrices. Numerical experiments demonstrated the effectiveness of the proposed approach.

可視光通信系における物理層セキュリティ基盤の構築

小島　駿
東京大学 生産技術研究所 特任助教

1.　研究背景

高速・大容量通信の需要増加に伴う周波数資源の逼迫問題を解決するために、可視光通信が注目されている。可視光通信は、IoT やドローン、自動車等でのユースケースが想定され、特に多数端末の同時接続を考慮する場合、軽量かつ安全なセキュリティ技術の実現は喫緊の課題である。従来では、計算量的安全性に基づく暗号方式を用いて通信の安全性を担保していたが、暗号化に係る計算量が莫大な点や量子コンピュータによる解読の脅威により、新たなセキュリティ基盤が要求されている。物理層秘密鍵生成(secret key generation: SKG)は、伝搬路のランダム性を用いて暗号化の鍵を生成する手法であり、軽量でかつ情報理論的安全性に基づくため、これらの課題の解決策の一つとして注目されている。本研究では可視光通信システムにおける高効率な SKG を実現することで、次世代可視光通信における新たなセキュリティオプションの確立を目標とする。

2.　提案手法

可視光通信においては、直進性が非常に高いため、伝搬路上のフェージング現象が乏しく、秘密鍵生成に必要な十分なランダム性をもつフェージングの誘発が困難であるという課題が存在する。従来の SKG では、このような環境下で十分なランダム性が確保できず、鍵生成の信頼性や安全性に疑問が生じる。そこで本研究では、鍵生成過程において十分なランダム性を供給する手法として、知能反射面（Reconfigurable Intelligent Surface: RIS）を活用した人工的マルチパス伝搬モデルによる SKG 方式を提案する。RIS は、入射する光信号に対し、各素子で独立に位相や反射角度を制御可能な反射面であり、意図的に伝搬路を形成する能力に優れている。提案方式では、RIS の制御パラメータとして反射角度をランダムに変動させることで、従来は存在しなかった多重反射経路を人工的に発生させ、チャネルのランダム性を拡大する。これにより、従来の VLC 環境においても十分なエントロピーが供給され、高い安全性を持つ秘密鍵の生成・共有が実現可能となる。

3.　結果

提案方式の有効性を検証するために、シミュレーションによる評価を実施した。屋内の VLC システムにおいて、2 つの正当な送受信機と 1 つの受動的な盗聴受信機がある設定とし、コヒーレンス時間内で安定なチャネルを想定した。また盗聴受信機は、正当な受信機で使用されるアルゴリズムを全て利用できる状態を仮定した。

シミュレーションでは、鍵誤り率・ランダム性テストの評価を行った。鍵誤り率の比較結果より、正当な送受信機では鍵誤りが信号対雑音電力比（signal-to-noise ratio: SNR）を大きくしていくにつれ性能が向上していくのに対し、盗聴受信機ではすべての SNR 領域で誤りが 0.5 となり、鍵情報にアクセスできていないことが確認された。またランダム性テストでは、従来の RIS を用いない場合では、7 つのテストのうち 2 つのみパスできているのに対し、提案方式を用いることで 7 つのテストすべてをパスできることが確認された。

4.　まとめ

本研究では、VLC に RIS を用いた安全な SKG 方式を提案した。RIS による反射をランダムに変化させることで、秘密鍵のエントロピーを増加させ、高い安全性を実現可能なことをシミュレーションにより示した。今後は、より高度な RIS の制御の実現・実機による評価を行っていく予定である。

Development of Physical Layer Security for Visible Light Communications

Shun Kojima
Project Research Associate, The University of Tokyo

1.　Introduction

To address the issue of scarce frequency resources resulting from the increasing demand for high-speed, high-capacity communications, visible light communication (VLC) has attracted significant attention. VLC is envisaged for applications such as IoT, drones, and automotive systems, where the simultaneous connection of many devices necessitates the realization of lightweight yet secure. Traditionally, communication security has been ensured by employing cryptographic methods based on computational security. However, the enormous computational load associated with encryption and the threat posed by quantum computer decryption have driven the need for a new security foundation. Physical layer secret key generation (SKG) is a technique that utilizes the inherent randomness of the propagation channel to generate encryption keys. Owing to its lightweight nature and information-theoretic security, SKG has emerged as a promising solution to these challenges. This research aims to establish a new security option for next-generation VLC by realizing highly efficient SKG in VLC systems.

2.　Proposed Method

In VLC, the extremely high directivity of light results in a weak presence of fading phenomena along the propagation path, making it difficult to induce the level of randomness necessary for SKG. Conventional SKG methods, under such conditions, are unable to secure adequate randomness, thereby raising concerns regarding both the reliability and the security of the generated keys. To overcome this challenge, this study proposes an SKG scheme based on an artificial multipath propagation model that leverages a reconfigurable intelligent surface (RIS) to supply sufficient randomness during the key generation process. An RIS is a reflective surface equipped with elements that can independently control both the phase and reflection angle of incident light signals, and it exhibits an exceptional capability for deliberately forming propagation paths. In the proposed approach, the reflection angle—a key control parameter of the RIS—is varied randomly. This random variation artificially induces multiple reflection paths that are absent in conventional VLC environments, thereby expanding the randomness of the communication channel. Consequently, even in typical VLC settings, adequate entropy is provided, making it possible to generate and share secret keys with a high level of security.

3.　Simulation Results

To verify the effectiveness of the proposed method, an evaluation is conducted via simulation. An indoor VLC system is considered, featuring a configuration with two legitimate transceivers and one passive eavesdropper receiver, while assuming a stable channel within the coherence time. It is further assumed that the eavesdropper had access to all the algorithms employed by the legitimate receiver.

In the simulation, evaluations are carried out on both the key error rate and the randomness tests. With respect to the key error rate, the results indicate that the legitimate transceivers exhibit improved performance as the signal-to-noise ratio (SNR) increased. In contrast, the eavesdropper receiver maintains an error rate of 0.5 across all SNR regions, thereby confirming that the eavesdropper is unable to access the key information. Moreover, the randomness tests demonstrate that while only two out of seven tests are passed in the absence of RIS, the proposed method enables all seven tests to be passed, thereby substantiating the effectiveness of the approach in supplying sufficient channel entropy for SKG.

4.　Conclusion

In this study, a secure SKG method utilizing RIS in VLC was proposed. By randomly varying the reflection characteristics through RIS, the entropy of the secret key was increased, and simulations demonstrated that high security can be achieved.

光ファイバ通信網の大容量化を実現するディジタル信号処理技術

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1. 背景と目的

通信トラフィックの爆発的な増加に伴い、光ファイバ通信網の容量拡大が急務となっている。その中で、光ファイバ 1 芯あたりの伝送効率を高める手段として、高密度波長分割多重が注目されており、それらを支える構成要素である波長選択スイッチ(Wavelength-selective switch: WSS)の特性が、通信品質に与える影響の推定及び制御が求められている。特に WSS は、多波長信号を選択・分離する過程で、スペクトル狭窄や帯域内クロストークといった劣化を引き起こすことが知られており、それらの影響は信号の高密度化・高次数化によってさらに顕著となる。本研究では、WSS を通過することで生じる光信号の品質劣化をモデル化・数値評価し、その劣化パターンの依存性（通過順・発生位置・フィルタ特性）を明らかにすることで、ディジタル信号処理の補償精度の向上を実現する。

2. 研究成果

本研究では、初めに WSS による光信号への劣化影響について解析を行った。劣化の発生位置（高周波側か低周波側）による復調性能の差、劣化順序の違いによる品質差、フィルタ特性の違いによる劣化度合いの変化、といった要因がそれぞれ独立ではなく複雑に相互作用することを示した。これらの結果を踏まえ、機械学習に基づく Digital longitudinal monitoring（DLM）技術の活用可能性についても検討を行った。DLM は、受信信号から伝送チャネル全体をディジタル再構成することで、伝送路中におけるスペクトル狭窄や中心周波数ずれなど複数の劣化要素を分離・特定可能とする。本技術は、光ファイバ伝送系内の線形・非線形演算の非可換性を利用することで、誤差逆伝搬によりチャネルの構造を推定するものである。本研究では、この技術をネットワーク制御へ応用するための検討を行い、WSS を含む光ノードの挙動をディジタル領域で把握・補償可能であることを確認した。また、複雑な光ネットワークが有する多様な構造情報を活用することで、劣化推定の精度をさらに向上させる手法についても検討しており、現在、学術雑誌への論文投稿を予定している。

本研究は、WSS による信号劣化の構造的理解とそのモデル化に加え、それらをディジタル信号処理により分離・推定・補償する技術の応用を示した点において、学術的・実用的に大きな意義を有する。特に、光ネットワークの高密度化・高次数化において不可避となる複雑な劣化要因に対し、信号処理と機械学習の融合により高精度かつ柔軟に対応可能な次世代の通信基盤技術としての展望を切り拓いた。これにより、運用中の複雑な光ネットワークにおけるリアルタイムな品質監視と自律的な資源制御が可能となり、過剰なマージンを排した大容量かつ効率的なネットワーク設計が実現可能となる。申請課題である「光ファイバ通信網の大容量化を実現するディジタル信号処理技術」に対して、本研究は、光ノードを含む伝送環境の動的な特性変動を前提とした次世代信号処理アーキテクチャの構築に寄与するものである。将来的には、AI を活用したネットワーク運用との連携や多段劣化補償処理の最適化などを通じて、光通信システムの信頼性・柔軟性・拡張性の向上に貢献することが期待される。

Digital Signal Processing Enabling Large-Capacity Photonic Networks

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Background and Objectives

With the growth of communication traffic, expanding the capacity of optical fiber networks has become an urgent challenge. Among the strategies to increase the transmission efficiency per optical fiber core, ultra-dense wavelength division multiplexing (WDM) has attracted significant attention. A key component that enables routing in such systems is the wavelength-selective switch (WSS), whose characteristics directly impact signal quality. In particular, WSSs are known to induce performance degradation such as spectrum narrowing and in-band crosstalk. These effects become more pronounced with increasing spectral density and modulation order.

This study aims to model and numerically evaluate the signal quality degradation caused by WSSs and to analyze its dependency on several factors, including the order of WSS traversal, the position of spectral distortion, and the filter characteristics. By doing so, we seek to improve the compensation accuracy of digital signal processing (DSP) techniques.

Research Achievements

We first analyzed the degradation effects introduced by WSSs on optical signals. The study revealed that degradation depends on various factors such as the spectral position, the sequence of WSS-induced filtering, and the specific filter shape. These factors interact in complex and non-independent ways, affecting the overall demodulation performance. Based on these findings, we further investigated the applicability of Digital longitudinal monitoring (DLM), a machine-learning-based approach that reconstructs the entire transmission channel digitally from the received signal. DLM enables the separation and identification of multiple degradation sources occurring within the transmission path. This technique leverages the non-commutative nature of linear and nonlinear operations in optical fiber channels and uses error backpropagation to estimate the channel structure.

We confirmed that this technology can be effectively applied to network control by enabling digital-domain monitoring and compensation of WSS behavior within optical nodes. Additionally, we explored methods to enhance estimation accuracy by utilizing the diverse structural information present in large-scale optical networks. The results of this study are currently being prepared for submission to an academic journal.

This research contributes both academically and practically by advancing the structural understanding and modeling of WSS-induced signal degradation and by demonstrating its application to separation, estimation, and compensation through DSP. In particular, it opens new directions for next-generation optical communication systems capable of flexibly and accurately addressing complex degradation factors that are unavoidable in high-density, high-order optical networks.

映像無線伝送を目的とした情報源・通信路結合符号化方式に関する研究

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まえがき

セマンティック通信の一種として、情報源通信路深層結合符号化方式（DeepJSCC）が注目を集めている［1]。従来の情報源符号化と通信路符号化の代わりに、自己符号化器を用いて、画像などの情報源を潜在空間に圧縮し、それを IQ シンボルに直接マッピングする。DeepJSCC は画像伝送を目的として、特に研究がなされており、低 SNR 領域でもクリフ効果を回避し、より高いピーク信号雑音比（PSNR）を実現するとシミュレーションにより報告されている。本研究助成では、ローカル 5G 基地局と端末を、外部機器から IQ 信号を送受できるよう改造し、DeepJSCC 信号を実環境で伝送することで、その特性を調査してきた。その結果について報告する。本稿では特に圧縮率を変化させたときの画像品質への影響についてまとめる。

DeepJSCC の構成

本稿で用いた DeepJSCC は、畳み込みニューラルネットワーク（CNN)を用いて設計されており、Encoder と Decoder に分けて、それぞれを送信機と受信機に配備する。Encoder は、2 次元畳み込み層 (Conv) と Generalized Divisive Normalization (GDN)層、PReLU 層から構成される 5 層程度の CNN である。Decoder は、Encoder と対照構造を持ち、Conv の代わりに 2 次元転置畳み込み層 (TransConv)を用いる。Encoder は、入力画像を複素ベースバンド信号に変換する操作を行う。Encoder 最後の Conv 層の出力チャネル数を変化させることで、画像の圧縮率を調整できる。出力シンボルは平均電力に基づいて正規化され、通信路に送信される。

屋外伝送実験

本実験では、画像データセットとして、ImageNet を採用した［2]。ImageNet の学習画像から、50,000 枚の画像を用いて学習を行った。テスト時には、ImageNet のテスト画像から、ランダムに 10,000 枚を抽出した。エンコーダの最終層の出力チャネル数は、4 から 12 に設定した。学習時、加法性白色ガウス雑音を通信路として仮定し、SNR を 6 dB に設定した。実験諸元について、今回は見通し環境（LoS）について、ローカル 5G 基地局[3]を用いて、大阪大学吹田キャンパス構内で実験を行った。基地局 gNB と端末 UE の間の距離は 120 m（LoS）とした。UE 側での受信信号強度（RSSI）は、中央値がそれぞれ-65,~-72 dBm であった。実験結果を図 1 に示す。図 1 から、良好な特性が得られていることがわかる。どの圧縮率に関しても、適応変調を実施せずとも、環境の変化に対応していることがわかる。

参考文献

[1] E. Bourtsoulatze et. al., IEEE Tran. Cog. Commun. Netw., **5**, 567, (2019)., [2] J. Deng et. al., Proc. IEEE CVPR, pp. 248-255, (2009)., [3] D. Hisano, TechRxiv, Jan. 2025.

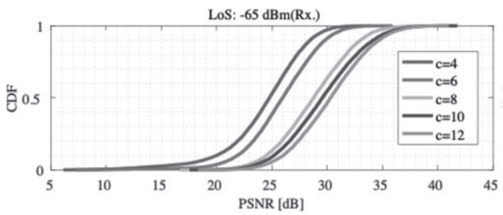

図 1 実験結果.

Deep Joint Source-Channel Coding for Wireless Video Transmission

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Introduction

As a type of semantic communication, Deep Joint Source-Channel Coding (DeepJSCC) has been attracting attention [1]. Instead of traditional separate source coding and channel coding, DeepJSCC compresses information sources, such as images, into a latent space using an autoencoder and directly maps them to IQ symbols. Research on DeepJSCC has been particularly focused on image transmission, with simulations reporting that it can avoid the cliff effect and achieve a higher Peak Signal-to-Noise Ratio (PSNR) even in low Signal-to-Noise Ratio (SNR) environments.

In this study, we modified a local 5G base station and terminal to enable external devices to send and receive IQ signals, allowing us to transmit DeepJSCC signals in a real environment. We investigated its characteristics and report our findings. This paper particularly summarizes the impact of varying compression ratios on image quality.

DeepJSCC

The DeepJSCC used in this study was designed using a Convolutional Neural Network (CNN), which was divided into an Encoder and a Decoder, assigned to the transmitter and receiver, respectively.

Encoder: Consists of a five-layer CNN comprising 2D convolutional layers (Conv), Generalized Divisive Normalization (GDN) layers, and PReLU layers. It transforms input images into complex baseband signals. The compression ratio of the image can be adjusted by changing the number of output channels in the final convolutional layer.

Decoder: Has a structure mirroring the encoder, but uses 2D transposed convolutional layers (TransConv) instead of Conv layers.

The output symbols are normalized based on their average power before transmission through the channel.

Outdoor Transmission Experiment

For this experiment, we used the ImageNet dataset [2]. **Training**: 50,000 images from the ImageNet training set were used for training. **Testing**: 10,000 randomly selected images from the ImageNet test set were used. **Parameter Settings**: The number of output channels in the final layer of the Encoder was varied from 4 to 12. Training was performed assuming an Additive White Gaussian Noise (AWGN) channel with an SNR of 6 dB.

For the experimental setup, we used a 5G base station [3] and conducted tests on the Osaka University under Line-of-Sight (LoS) conditions. The distance between the base station (gNB) and the terminal (UE) was 120 m. The received signal strength indicator (RSSI) at the UE had a median value ranging from -65 dBm to -72 dBm.

The results of the experiment are shown in Figure 1. From the figure, it is evident that good performance was achieved. The system successfully adapted to environmental changes without requiring adaptive modulation, regardless of the compression ratio.

Reference: [1] E. Bourtsoulatze et. al., IEEE Tran. Cog. Commun. Netw., **5**, 567, (2019)., [2] J. Deng et. al., Proc. IEEE CVPR, pp. 248-255, (2009)., [3] D. Hisano, TechRxiv, Jan. 2025.

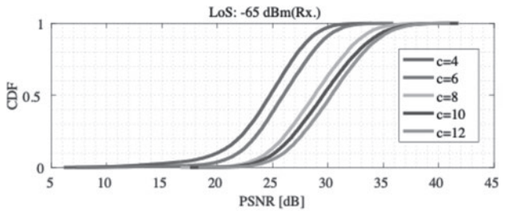

Figure 1 Experimental results.

超低遅延・大容量光ネットワークのための全光信号処理技術に関する研究

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1.　研究背景および研究目的

第五世代移動通信システム（5G）では 1 ミリ秒以下の遅延時間を目標としているが、これは無線区間のみの遅延時間であり、有線の光通信ネットワークを介して遠隔サーバー通信を行う際には数十ミリ秒の遅延時間が生じる場合があり、有線区間の遅延がボトルネックとなる。本研究では、光通信ネットワークの光ノードにおける遅延を低減するための要素技術の一つとして、光ノードの変調フォーマット変換処理を光のまま実現する技術の確立を目指す。その中でも、大容量化通信向け偏波多重光信号の一括変換技術に着目し、計算機シミュレーションおよび実験によりその実現可能性を示した。

2.　実施内容

偏波多重信号の変調フォーマット変換を行うには、2 つの偏波間の影響を抑えて独立に光信号処理を行う必要がある。光デバイスの偏波依存性や偏波間干渉が大きく影響するため、集積型光デバイスの非線形光学効果を用いた場合、偏波多重した光信号を一つの光デバイスで同時に信号処理するのは困難である。光ファイバ中の非線形光学効果を用いる場合においても 2 つの偏波間の干渉が存在するが、偏波保持高非線形ファイバ（PM-HNLF: Polarization-Maintaining Highly Nonlinear Fiber）を用いることにより偏波間干渉を最小限に抑えられる。

本研究では、データセンター間通信で使われる 4 値パルス振幅変調（PAM4: 4-level Pulse Amplitude Modulation）方式から 4 相位相シフトキーイング（QPSK: Quadrature Phase Shift Keying）方式に変換する全光変調フォーマット変換の手法を提案し、計算機シミュレーションおよび実験により提案する変換手法の原理確認、変換性能の調査を行った。具体的には以下の①〜③の研究項目を実施した。

① 偏波多重信号の全光 PAM4/QPSK 変換器の構成を検討した。
② 変換器の動作特性および最適動作条件を計算機シミュレーションにより明らかにした。
③ 変換器の基本動作を実験により実証した。

代表的な結果として、実験で得られた返還後の QPSK 信号のコンステレーションダイアグラムを図 1 に示す。x 偏波, y 偏波共にエラーベクトル振幅が 23〜24%となり、エラーフリーの変換動作が実現できることを確認した。本研究で得られた成果を国際会議にて発表した[1]。

3.　成果発表

[1] Y. Fujihara, D. Hisano, A. Maruta, and K. Mishina, “All-optical Modulation Format Conversion from DP-PAM4 to DP-QPSK Using PM-HNLF,” in Proc. of 29th Optoelectronics and Communications Conference (OECC 2024), Paper #75, Melbourne, Australia, July 2024.

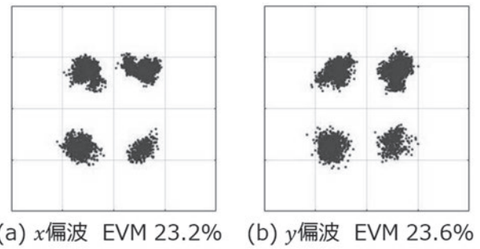

図 1　実験結果：変換後の QPSK 信号のコンステレーションダイアグラム

Study on All-Optical Signal Processing for Ultra-Low-Latency and High-Capacity Optical Networks

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1.　Research background

The fifth-generation mobile communication system (5G) aims to achieve a latency of less than 1 millisecond, which includes only the latency of the wireless section. When remote server communications are carried out via an optical fiber communication network, there is a concern of latency of tens of milliseconds, which results in the bottleneck of the latency. In this study, I aim to develop an all-optical modulation format conversion processing in optical communication networks to reduce the latency at optical nodes. In particular, I focused on the technology for simultaneous conversion of polarization-multiplexed (PM) optical signals for high-capacity transmission and demonstrated its feasibility through numerical simulations and experiments.

2.　Implementation details

To achieve the modulation format conversion of the PM signals, it is necessary to perform optical signal processing independently while suppressing the effects between the two polarization components. Since the polarization dependence of optical devices and polarization interference have a significant effect, it is difficult to simultaneously process polarization multiplexed optical signals using a single optical device when using the nonlinear optical effects of integrated optical devices. Even when using nonlinear optical effects in optical fibers, there is interference between the two polarization components. However, by using polarization-maintaining highly nonlinear fiber (PM-HNLF), the interference between the two polarization components can be minimized.

In this study, I proposed a method for all-optical modulation format conversion that converts a PM 4-level pulse amplitude modulation (PAM4) signal to a PM quadrature phase shift keying (QPSK) signal used in data center networks. I confirmed the principle of the proposed conversion method and investigated the conversion performance through numerical simulations and experiments. I carried out the following research items ①−③.

① Developing the configuration of the all-optical PAM4/QPSK converter for the PM signal.
② Discussing the operating characteristics and optimal operating conditions of the converter.
③ Demonstrating the basic operation of the converter using experiments.

In the experiment, the error vector magnitudes of the converted QPSK signals were 23−24% for both the x- and y-polarization components. It was confirmed that an error-free conversion operation could be achieved. The results obtained in this study were presented at an international conference [1].

3.　Publication

[1] Y. Fujihara, D. Hisano, A. Maruta, and K. Mishina, “All-optical Modulation Format Conversion from DP-PAM4 to DP-QPSK Using PM-HNLF,” in Proc. of 29th Optoelectronics and Communications Conference (OECC 2024), Paper #75, Melbourne, Australia, July 2024.

データ駆動型材料開発に資する外挿と説明が可能な数学モデルを見出すAIに関する研究

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研究背景と目的

産業界がAI技術に期待していることは、【人・時間・コスト（エネルギーも含む）の効率・省力化】を実現するための指針、つまり、意思決定ツールとしての活用である。しかし、近年活発に研究開発されているAIの出力は、❶学習データの範囲を脱することは出来ない（内挿型のAI）、❷学習データの量に大きく左右される、❸結果を導くロジックは常にブラックボックスが付き纏う、ことが課題である。材料分野の企業は、AIに【新規材料を見出す手段】としての役割を期待しており、データ駆動型材料開発を推し進めようとしている。しかし、AIを構築するために大量の教師データを人間が取得し、その学習データに特化した内挿型の評価AIを増産しているのが現状である。

この様な状況を鑑み、AI技術を1つの方策としてデータ駆動型材料開発を本来あるべき方向性へ修正することが、申請者の最終目的である。そのためには、少ない材料系の実験データからでも外挿による予測とモデルの説明が可能な数学モデルを見出すAIを構築することが、必要不可欠であると考える。

提案手法

容易に様々な学習データを生成可能であることから、以下に示す要素で構成される仮説のAIモデルを力学の基礎問題に対して適用することで、実現性の可否を検証することとした。

① 単位を含む実験データの入力部
② 様々な関数形を予め機械学習させた分類機、もしくは実験データの挙動や相関性からモデル化の可能性がある関数形を提案する生成機
③ 実験データの挙動や相関性から提案モデルの適・不適を分類することで、よりモデル化の可能性が高い関数形を抽出する分類機
④ 提案された関数形を実験データに回帰し数学モデルを見出す評価機

研究成果

これまで材料分野の研究に従事してきた申請者が、自身が提案するAIをゼロから構築することは、想像以上にハードルが高い研究であることを思い知らされた。以下に研究実施期間中に行った研究内容を記す。

1. 提案手法①に記載のデータ入力部を構築した。
2. 提案手法②と③の機能を合わせ持った処理部の基本設計を行った。
3. 実験データから数学モデルを見出すPythonのライブラリーを活用し、提案手法④に資する評価機の基本設計を行った。

まとめと今後の展開

外挿と説明可能な数学モデルを見出すAIを構築するには、単位を含む実験データをどの様に取り扱い、どの様なロジックで処理することで実現することが出来るのかを再考した。

今後は早期にモデルを構築し、実現性の可否を検証する予定である。

Research on AI to Generate the Extrapolation and Explainable Mathematical Models Leading to the Development of Data-Driven Materials

Daisuke Shimamoto
Senior Research Scientist, National Institute of Advanced Industrial Science and Technology

[Introduction]

AI technology is expected by the industry as a guide to achieve efficiency and labor savings in terms of people, time, and costs. In other words, the industry wants to use AI as a decision-making tool. However, the output of AI has been researched and developed in recent years have the following challenges: ❶ It is not possible to escape the scope of training data (interpolation-type AI), ❷ It is heavily influenced by the amount of training data, and ❸ The logic always contains a black box. As materials companies seek to advance data-driven materials development, AI is expected to play a role as a means of discovering new materials. However, the current situation is that humans are acquiring large amounts of training data to build AI, and interpolation-type evaluation AI specialized for this learning data is being produced in large quantities.

In light of this situation, the ultimate objective is to utilize AI technology as a corrective measure to align data-driven material development with its intended trajectory. It is imperative to develop artificial intelligence capable of identifying mathematical models that facilitate predictions and elucidate models through extrapolation, even with limited experimental data on material systems.

[Proposed method]

Because training data can be generated easily, I applied an AI model consisting of the 4 elements shown below to a basic problem in mechanics to verify its feasibility.

① Input section for experimental data
② A classifier that has learned various functional forms, or a generator that proposes functional forms that can be modeled based on the behavior and correlation of experimental data
③ A classification machine that classifies the suitability of the proposed model based on the behavior and correlation of the experimental data and extracts the function
④ An evaluation machine that regresses the proposed function form to experimental data to find a mathematical model

[Research Results]

The applicant, who has been engaged in different fields of research, realized that building AI was a much higher hurdle than I had imagined. The following is a summary of the research carried out during the research period.

1. The data input section described in proposed method ① has been constructed.
2. A basic design of a processing section was created that combined the functions of proposed methods ② and ③.
3. The basic design of an evaluation machine contributing to proposed method ④ was created by utilizing a library that derives mathematical models from experimental data.

[Summary and future developments]

To build an AI that can extrapolate and find explainable mathematical models, I reconsidered how to handle experimental data that includes units and what kind of logic can be used to process it. I plan to build a model soon and verify its feasibility.

ユーザの包括的な状態理解に基づき QOL 向上に導く対話システムの開発

中川　聡
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1. 研究背景と目的

遠隔通信技術の進展に伴い人同士のつながりが希薄化する中、QOL（Quality of Life）向上を支援する新しいコミュニケーション技術が求められている。本研究では、視線・音声・表情・発話内容などのマルチモーダル情報を統合して QOL を推定し、推定結果に基づき、共感的な応答を生成する対話支援システムを構築した。また、LINE ボットや対話ロボットを通じた実証実験も行い、関係構築促進や行動変容支援への有効性を確認した。本研究の目的は、一人一人に応じた対話支援を通じた Well-being Centered Society の創出である。

2. 研究の実施内容

(1) マルチモーダル QOL 推定：視線・表情・音声・発話を統合し、QOL をリアルタイムで推定するシステムを開発。また、推定された QOL に基づいて言動を生成する対話システムを開発。高齢者の精神的 QOL を有意に向上させたことを確認。IEEE ICDH 2024 で発表。
(2) 共感的言動生成：共感 6 要素に基づき、共感的対話エージェントを開発。LINE や対話ロボットを用いて実装・検証。日本生体医工学会で発表。
(3) 関係構築促進：対立する 2 者間に共感的言動生成を行う対話支援システムを介在させ、対立緩和を実現。共感度や自己開示度の有意な向上を確認し、人工知能学会で発表し、全国大会優秀賞を受賞。その他、対話ロボットに適用した研究成果を日本ロボット学会で発表。

3. 得られた成果

QOL 推定技術の確立および QOL 向上に資する対話システムを実装し、上述の通り複数の学会で成果発表を行い、内 1 件で受賞した。現在、国内学会と国際学会の各 1 件で採択通知待ちである。また、発表を通じて新たに得た人脈により、日本法社会学会でのセミナー発表や民間企業との連携も始動し、更なる成果展開を実現できた。

4. 今後の展望

本研究で得られたコミュニケーションの新たなあり方は、AI 技術の活用により人々の能力や関係促進を図る人間中心インタラクションの創出に貢献すると考える。今後はより一層社会実装に向けた取り組みの展開を目指し、高齢者の孤立防止、教育現場での社会性獲得支援、世代間交流の活性化など、高齢者福祉、教育工学、精神医学などの隣り合った領域との共同を行う。また、AI 介入による影響も今後の重要課題となりうることから、倫理性、透明性の担保も考慮に入れた研究活動を行う。

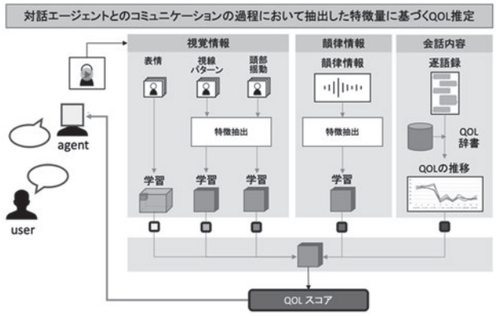

図 1．マルチモーダル QOL 推定システム概略図

謝辞

本年度に新設された研究室での活動は私にとって重要な年であったが、大川情報通信基金のご支援により研究活動に邁進できた。また、後継者の育成、産学連携の推進、国際的な人脈構築といった今後の研究基盤の構築も大きく加速された。加えて、貴財団主催の研究助成オンラインフォーラムや懇談会を通じて、多くの人脈を構築し、自身の研究の方向性を再認識することもできた。
貴財団の皆様に、改めて厚く感謝申し上げます。

Development of a Dialogue System Guiding QOL Improvement Based on Comprehensive User Understanding

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1. Research Background and Objectives

This research developed a multimodal dialogue support system that estimates users' QOL by integrating gaze, voice, facial expressions, and speech content, and generates empathetic responses based on the estimated states. The effectiveness of this system was validated through practical experiments, confirming its utility in supporting relationship building and behavioral change. The objective of this study is to contribute to the realization of a Well-being Centered Society through personalized, empathetic communication support.

2. Research Implementation

We developed a real-time QOL estimation system that integrates gaze, facial expressions, voice, and speech, and a dialogue system that generates verbal behavior based on the estimated QOL. The system significantly improved participants' psychological QOL, especially among older adults. Results were presented at IEEE ICDH 2024. An empathetic dialogue agent was also implemented based on six elements of empathy. It was tested via LINE bots and communication robots, with results presented at a conference in Japan. Furthermore, we introduced the dialogue system between pairs with conflicting opinions and found that it mitigated tension and significantly improved empathy and self-disclosure. These results were presented at the Japanese Society for Artificial Intelligence (JSAI), where the work received the Best Paper Award. An extended version of this study has been submitted to HCII 2025 and is currently under review.

3. Achievements

This research successfully established a QOL estimation technique and implemented a dialogue system that contributes to QOL improvement. As outlined above, the outcomes were presented at multiple academic conferences, including one that received an award. In addition, the research has expanded through new collaborations, including a seminar presentation at the Japan Association of Sociology of Law and an emerging partnership with a company.

4. Future Direction

The proposed communication framework contributes to the development of human-centered interaction, where AI enhances interpersonal capabilities and social connection. Moving forward, we aim to advance the social implementation of this research, particularly in areas such as elderly care, education, and intergenerational communication. Collaborations are planned with related fields such as welfare and educational technology.

Acknowledgments

This fiscal year marked the beginning of our newly established research laboratory. The generous support from the Okawa Foundation enabled us to focus intensively on our research activities. The grant also greatly accelerated the development of a foundation for future research, including mentoring students, fostering industry-academia collaboration, and building international networks. I would like to express my deepest gratitude to all members of the Okawa Foundation.

in silico シミュレーションを用いた凍結保護剤設計基盤

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1. 緒言

凍結保護剤（CPA）は細胞を凍結傷害から守るための物質であり、ジメチルスルホキシド（DMSO）にその効果があることが発見され、現在でも広く用いられる。しかし、DMSO は幹細胞に対して毒性を示し、分化因子として働く特性があり、DMSO に代わる CPA 開発が急務である。これまでに、天然由来の化合物をベースに開発や、シミュレーションを用いた評価による探索が行われた。しかし、現状ではあらゆる化合物を網羅的に考慮することは困難である。そこで、本研究では、網羅的に化合物を考慮できる CPA のコンピュータ支援設計に取り組んだ。

2. 分子設計手法

Mazur によると、凍結傷害の原因は、細胞内氷晶形成と溶液の凍結濃縮に分類される。そこで、前者を防ぐ物性を計算化学的に評価し、後者の影響を防ぐ物性を実験的に評価した上で、細胞を用いた検証実験を行った。

2.1. 計算化学的評価

氷晶形成を防ぐ上で、重要な物性値であると考えた分子量（Mw[–]）、分配係数（$log\ P$[–]）、極性表面積（$TPSA$[m^2]）を特徴量として抽出した。そして、基準化合物と化合物jの物性値距離$D(j)$[–]を最小化する最適化問題により、実験的評価・検証実験をする物質を選択した。

2.2. 実験的評価

凍結濃縮の影響を防ぐ物性値として、細胞膜への活性値$A(j)$[J g^{-1} M^{-1}]を求めた。$A(j)$が小さいほど、細胞膜を安定化する。1.5%の寒天溶液に化合物jを加えた時のゲル化点変化ΔT_j[K]を試験管傾斜法で測定（$n = 3$）し、$A(j)$を算出した。

2.3. 検証実験

スクリーニングにより選び出された化合物を用いて凍結実験を行い、解凍後の細胞生存率を評価することで、各化合物の凍結保護効果に関する検証を行った（$n = 1$）。

3. 設計手順の適用

3.1. 適用（1 回目）

計算化学的評価により、分子量 100 以下である 911 種類の化合物から 4 物質を選び出した。そして、4 物質を用いて凍結実験を行ったところ、解凍後の細胞生存率$r(j)$[–]がネガティブコントロールと同等（$r(j) = 0.127$）だった。これは、4 物質は全て常温で固体であることや、塩でなければ水に難溶であることが原因だと考えられる。

3.2. 適用（2 回目）

計算化学的評価により、分子量 150 以下、常温で液体、水と混和性の 80 種類の化合物から 4 物質を選び出し、実験的評価と凍結実験を行った。細胞生存率$r(j)$が高かった 2 物質およびポジティブコントロール（P.C.）の結果を**表 1** に示す。$r(j)$は改善されているため、致命的な凍結傷害である細胞内氷晶の生成・成長を防ぐことができていると考えられる。1-メチルイミダゾールとピリダジンはヘテロ環アミンであり、これはアミンが氷晶成長を抑制したからだと考えられる。

表 1 評価・検証実験結果

候補物質	$D(j)$ [–]	$A(j)$ [J g^{-1} K^{-1}]	$r(j)$ [–]
1-メチルイミダゾール	0.277	37.6 ± 2.30	0.696
ピリダジン	0.645	21.3 ± 3.46	0.485
DMSO（P.C.）	0	–2.26 ± 2.41	1.01

4. 結言と今後の展望

網羅的に化合物を考慮できる CPA 設計手順を確立し、それを繰り返し用いることで、より凍結保護効果の高い CPA を設計することできることが分かった。

Design Platform of Cryoprotective Agents with *in silico* Simulation

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Stem cell therapy has recently emerged as a key player in regenerative medicine. Along with recent successful clinical studies using stem cells, the implementation of stem-cell-based medical treatments is in progress. In stem cell manufacturing, freezing processes are one of the most critical steps because the process is needed to the transportation and preservation of the cells. Cryoprotective agents (CPAs) are used to protect cells from freezing injuries. Dimethyl sulfoxide (DMSO) was discovered to have cryoprotective effects and is still widely used today, although DMSO is toxic to stem cells and has the property of acting as a differentiation factor. Thus, it is urgently needed to develop alternative compounds for DMSO.

In the field of process systems engineering, computer-aided molecular design (CAMD) and large-scale screening have been intensively explored. Liu et al. developed a computer-aided toolbox for molecular and mixture product design problems. Ten et al presented a CAMD framework by incorporating safety and occupational health aspects. Valencia-Marquez et al. proposed a CAMD approach for an ionic liquid-based lubricant. However, regarding CPAs, CAMD and large-scale screening are yet to be applied.

This work presents an exploration of CPAs for stem cell manufacturing using CAMD approaches that can comprehensively consider compounds. From a CAMD perspective, it is necessary to convert requirements into physical properties, although it is unclear which properties are related to cryoprotective effects. Therefore, we developed an exploration cycle that can expose better candidates by incorporating domain knowledge through discussions with experts from the field of biotechnology.

The developed cycle was performed twice for exploration of CPAs. As a result, 1-methylimidazole and pyridazine were selected as promising CPA candidate compounds, which were both heterocyclic amines, although the attachment efficiency was low. The application of the developed cycle focusing on heterocyclic amines could lead to more effective designs of CPAs for stem cells. Using the exploration cycle repeatedly, CPA candidate compounds with better cryoprotective effects, i.e., both high cell survival rates and attachment efficiency, could be discovered.

Future work includes applying the developed cycle to other heterocyclic amines. Another research opportunity would be to combine this approach with the previous process design models for the process design step. Furthermore, the developed approach should be applied to development of other materials related to cell manufacturing to confirm the generality of the approach.

異種センサ統合と能動学習による組立作業時の高精度な迷い推定

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1　背景および目的

近年、セル生産方式が導入される中で、非熟練者向けの作業支援システムの研究が進んでいる。適度な難しさを持つ支援が作業効率と心地よさの両立に寄与することが示唆されており、本研究では作業の難しさを「迷い」として捉え、その種類とレベルを推定することを目的とした。また、個人に特化した推定モデルの方が高精度であるため、教師付き機械学習の一種である能動学習を用いてモデルを使用中に更新する機構の導入を目指した（図 1）。

2　取り組みと成果

2.1 異種センサによる迷い推定手法の開発と実装

迷いの推定を 5 クラス分類問題（迷いなし・部品探索（高低）・部品取付（高低））として定義し、視線遷移データ（414 次元）と視線と手の位置データ（19 次元）を特徴量として利用した。そして迷いの有無と種類を始めに 3 クラス分類し、確信度が一定値以上のデータに対して強弱を分類する「棄却オプション付き階層型モデル」を提案し（F 値=0.533）、5 クラスを一括分類するモデル（F 値=0.514）を上回る性能を確認した[1]。さらに、迷いが交感神経へ及ぼす影響を検討するため、光学式脈波センサで取得した脈波データの利用を検討したが、個人差が大きく迷い推定への活用は見送った。

2.2 能動学習手法の検討と MR 環境への移植

利用者に正解ラベルのアノテーションを依頼するサンプルの選択基準として Least Confident (LC)、Margin Sampling (MS), Entropy (ES)、無作為選抜 (RS)を比較した。いずれも、シミュレーションでは F 値の向上は見られたものの、500 回程度の復元抽出更新後でも 0.10 未満の増加に留まった（図 2）。続いて、迷い推定機能の MR 環境（Microsoft HoloLens2）への移植と能動学習機能の実装を行い、

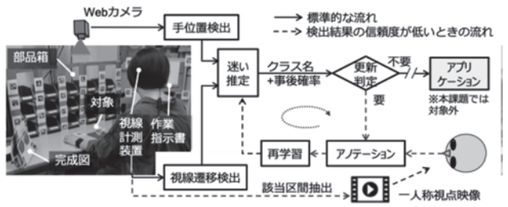

図 1　能動学習による迷い推定機能の逐次更新

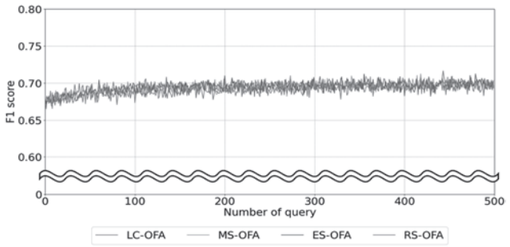

図 2　各種選択基準による学習曲線

アノテーション頻度（5、10、20 作業単位毎）を評価する実験を 12 名に対して実施した。その結果、10 作業単位毎が割り込み負担と想起の確信度のバランスが最適であることを確認した[2]。

3　まとめと今後の展望

本研究では、MR 環境下で能動学習を用いて逐次的に迷い推定機能を更新する機構の実装に成功した。しかし、学習効率の大幅な向上には至らなかったため、今後は特徴量の再検討や長期的なデータ収集を通じたモデルの改善を進める予定である。

対外発表

[1] T. Muragi, A. Tsuji and K. Fujinami. A System for Assembly-Work-Confusion Recognition based on Gaze and Hand Positional Information, *IJABC*, Vol. 2024, Issue 2, Article 22, June 2024.
[2] 高野、長瀬、辻、藤波。複合現実空間での組み立て作業中の迷いの推定とその逐次個別化、情処学会第 87 回全国大会、4ZC-05、2025 年 3 月。

Confusion Recognition in Assembly Tasks Based on Multi-Modal Sensor Fusion and Active Learning

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1.　Background and Objective

The cell production system, where workers assemble products from start to finish, is becoming widespread. Research on support systems for unskilled workers suggests that balancing efficiency and comfort requires an appropriate level of challenge. This study defines “confusion” as an indicator of the challenge and aims to estimate its type (part search or mounting) and level (high or low). Since personalized models improve accuracy, we introduced an active learning mechanism to update the model during use (Fig. 1).

2.　Approach and Results

2.1 Confusion Recognition

Confusion was classified into five categories: no hesitation, parts search (high/low), and parts attachment (high/low). Features were extracted from gaze transitions (414 dimensions) and gaze and hand positions (19 dimensions). A hierarchical model first classified the presence and type of confusion, then its intensity if confidence was high. This approach (F1-score: 0.533) outperformed a direct five-class classification model (F1-score: 0.514) [1]. Furthermore, to examine the physiological effects of confusion, pulse wave data were analyzed; however, large individual differences prevented further application.

2.2 Active Learning & Prototype

Four active learning strategies—margin sampling, least confidence, entropy, and random selection—were compared. All slightly improved the F1-score, but gains remained below 0.10 after 500 iterations (Fig. 2). A prototype on Microsoft HoloLens 2

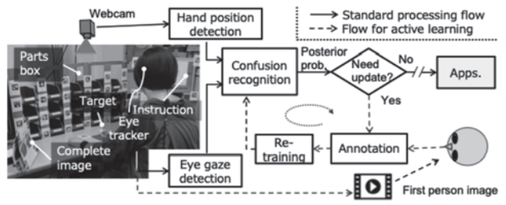

Fig. 1 Proposed confusion recognition framework

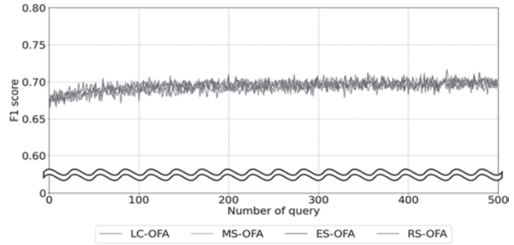

Fig. 2 Learning curves with active learning

integrated confusion recognition and active learning. A user study (12 participants) evaluated annotation intervals (5, 10, or 20 task units). The 10-task units showed the best balance between the annotator’s burden and the confidence of recall [2].

3.　Conclusion & Future Work

A Mixed Reality-based confusion recognition system with active learning was implemented but lacked efficient model updates. Future work will refine features and analyze the impact of long-term update to enhance model performance.

Publication

[1] T. Muragi, *et al.*, *IJABC*, Vol. 2024, Issue 2, Article 22, June 2024.
[2] Y. Takano, *et al. The 87th National Convention of IPSJ*, 4ZC-05, March 2025. (in Japanese)

新規画像補正技術と機械学習・深層学習を用いた潰瘍性大腸炎の自動診断システムの開発

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【目的】本研究では、①実用的な汎用画像フォーマットに対応したシステム・ユーザーインターフェースを開発すること、②様々な画質や色相・色調をもつ画像データを深層学習の手法で均質化すること、③これまでに申請者らが開発した深層学習・機械学習の成果をさらに発展させ、潰瘍性大腸炎(UC)の内視鏡診断において、社会実装可能な診断精度とすることが目的である。

【方法】

1. 深層学習による高画質化処理：敵対的生成ネットワーク(GAN)を用いて 4K 相当（3840×2160 ピクセル）の画像を生成する。

2. 最適な色相・色調補正技術の開発： Python Open CV、ライブラリを用いて、色相・色調補正用セットのヒストグラムを取得する。histogram matching を用いて、多様な機種から取得した内視鏡画像の色相を補正し、均質化する。

3. 自動診断プログラムの開発と精度向上：画像セットを学習・検証・テストデータに分割し、Python の異常検知アルゴリズム「Patchcore」や画像分類 CNN モデルを読み込み、「UC あり・なし」を弁別する。出力されたデータ画像を取得し、表示するプログラムを開発する。

【結果】正常・UC の内視鏡画像をそれぞれ 1,000 画像ずつ追加し、正常画像 約 2,000 枚・UC 画像約 4,000 枚のデータセットを作成した。

1. **深層学習による高画質化処理**
   データセットの画像を用いて、敵対的生成ネットワーク(Generative Adversarial Networks; GAN)の一手法である ESRGAN・CUGAN を用いて、4K 相当の画像を作成することに成功した。現行の AI 学習モデルでは 4K 相当画像への対応が確認できず、学習モデルの検証が必要とされ、次年度以降の課題とする。

2. **最適な色相・色調補正技術の開発**
   異なる機種により撮像された画像は色相・色調が異なり、機械学習の妨げとなる要因であった。特定の画像に合わせた色調補正技術を確立したが、実装化に向けては内視鏡画像に特化した色相補正技術の確立と自動化を進める必要があった。明るさとトーンカーブに着目し、解析対象となる内視鏡画像を基準画像に合わせた色調補正を行う自動化アプリケーションを開発した。

3. **自動診断プログラムの開発と精度向上**
   正常・UC 画像を多数収集し、異常検知アルゴリズム Patchcore および深層学習による学習モデルによる診断精度の検証を重ねたところ、Patchcore を用いた異常検知モデルに比べ Resnet50 や EfficientNet を用いた画像分類モデルにおいて診断精度が優れていることが明らかとなり、この学習モデルを用いた自動診断アプリケーションを開発した。加えて、説明可能な AI モデルを用いて、学習モデルによる判定時にどのピクセルに強く反応したかを出力することが可能となった。

【まとめ】新規画像補正技術と人工知能を用いた潰瘍性大腸炎の自動診断システムの開発を行った。実装化に向け、検証開発を進める。

Development of an AI-Based Ulcerative Colitis Diagnosis System Using Advanced Image Correction and Deep Learning

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【Aims】The aims of this study are following as: (1) to develop a system compatible with practical, general-purpose image formats, (2) to homogenize image data with various levels of quality, hue, and tone using deep learning techniques, and (3) to further advance the deep learning and machine learning outcomes in order to achieve a diagnostic accuracy for endoscopic diagnosis of ulcerative colitis (UC) suitable for real-world implementation.

【 Methods 】 1. High-Resolution Processing Using Deep Learning: We Generate 4K-equivalent images using Generative Adversarial Networks (GANs).**2. Development of Optimal Hue and Tone Correction Techniques**: Using Python OpenCV and libraries, we obtain histograms from images for hue and tone correction. We adjust and standardize the hues of endoscopic images obtained from various devices using histogram matching. **3. Development and Accuracy Improvement of an Automated Diagnosis Program**: Image sets are divided into training, validation, and test datasets. We load the PatchCore algorithm and CNN models to distinguish between the presence or absence of UC. We develop a program to obtain and display the generated images in addition to the results of diagnosis.

【Results】1.High-Resolution Processing Using Deep Learning: 4K-equivalent images were successfully generated with ESRGAN and CUGAN. However, the current AI training models have not been confirmed to support 4K-equivalent images, indicating a need for further validation of these models.

2. Development of Optimal Hue and Tone Correction Techniques: Images captured with different endoscope models exhibited variations in hue and tone, which posed challenges for machine learning. Tone correction techniques tailored to specific images were established. Focusing on brightness and tone curves, an automated application was developed to adjust the tone of endoscopic images to match a reference image.

3. Development and Accuracy Improvement of an Automated Diagnosis Program: A diagnostic accuracy was evaluated using both the anomaly detection algorithm Patchcore and deep learning-based classification models. The results revealed that image classification models using ResNet50 and EfficientNet outperformed the anomaly detection model using Patchcore in terms of diagnostic accuracy. Additionally, by utilizing an explainable AI (XAI) model, it became possible to highlight the pixels that contributed to the model's decision. Based on this finding, an automated diagnosis application was developed using CNN model and XAI.

【 Conclusion 】 We developed an automated diagnosis system for ulcerative colitis utilizing novel image correction techniques and artificial intelligence. Further verification and development will be pursued to enable practical implementation.

磁界及び情報通信技術を用いた駅プラットフォームにおける視覚障害者用バリアフリーシステムの開発

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近年、視覚障害者の駅プラットフォームからの転落事故対策として鉄道関係会社は、ホームドアーの設置に取り組んでいる。しかし、一駅に設置するホームドアーのコストは数億円以上と言われており、全ての駅に設置することは困難とされている。本研究では、低コストで安全性を保証すべく、新たなシステムの開発に取り組む。例えば、駅のプラットフォーム端は危険領域であるため、その領域に低周波数の磁界をトリガーコイルから発生させる。この磁界の領域を３次元で制御し、視覚障害者が所持するＩＤ付き検知タグが、磁界を検知すると、リーダー受信機にて視覚障害者の位置情報を把握し、危険領域にいることをアラームや音声等で知らせる。また、駅の下り階段手前や電車のドアーの位置情報を提供できるようにする。さらに複数の視覚障害者が駅を利用する際もＩＤ付きタグにより、誰がどこにいるか、ＰＣで管理できるようにする。

システム①：検知システム（図１）
電線コイルから磁界が発生し、タグが磁界を検知すると危険情報をタグの振動およびスピーカーから音声で提供する。音声は、2 種類（“まものなく下り階段です。“”ドアーの近くです。“）録音して製作した。さらに、パトライトを設置して光でも危険情報を提供できるようにした。パトライトの色は、目に優しい緑色とした。実際に駅にて動作確認を行い、問題なく機能することを確認した。

システム②：管理システム（図２）
電線コイルから磁界をある空間に発生させ、タグを持って空間内に入るとタグ情報を無線にて管理室に自動的に送付し、この空間内にいる限り、情報は送付し続ける。この空間から外に出るとタグ情報は提供されないため、いつ誰がどこにいるか管理できる。記録としてエクセルに自動保存できるようにしている。

これらのシステムを視覚障碍者に確認いただいた。安全を確認できること、また周りの人に見守っていただけることについて安心できるとコメントいただいた。今後、この技術を基礎として実用化に一歩、近づけたと考えている。

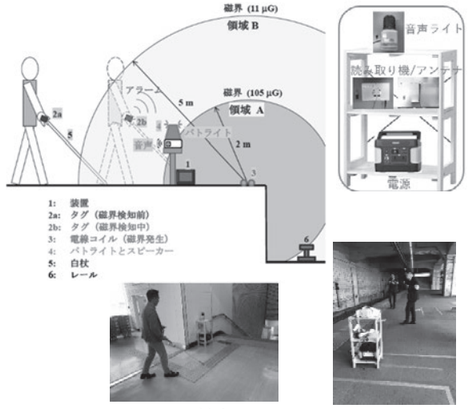

図１　検知システム

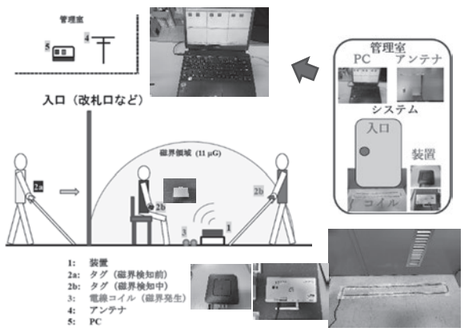

図２　管理システム

Development on Barrier Free System Using Magnetic Fields and Information and Communication Technology for Blind People on Station Platform

Mitsuhiro Okayasu
Professor, Okayama University

In recent years, railway companies have been installing platform doors as a countermeasure against falls from train platforms involving visually impaired individuals. However, the cost of installing platform doors at a single station is said to exceed several hundred million yen, making it difficult to implement them at all stations.

This study focuses on developing a new system to ensure safety at a lower cost. For example, since the edge of a train platform is a hazardous area, a low-frequency magnetic field is generated from a trigger coil in that region. By controlling this magnetic field in three dimensions, a detection tag with an ID carried by visually impaired individuals can detect the magnetic field. Upon detection, the reader receiver identifies their location and alerts them using alarms or voice notifications. Additionally, the system provides information on the location of descending staircases and train doors. Moreover, when multiple visually impaired individuals are present at the station, their locations can be monitored and managed via a PC using ID-equipped tags.

・System ①: Detection System (Figure 1)

A magnetic field is generated from an electric wire coil, and when the detection tag senses this magnetic field, it provides danger notifications through vibrations and voice output from a speaker. Two pre-recorded voice messages were created: "You are approaching a descending staircase." and "You are near the train door." Furthermore, a patrol light was installed to provide visual alerts. The patrol light was designed with a green color to be gentle on the eyes. A functional verification test was conducted at an actual train station, confirming that the system operates without issues.

・System ②: Management System (Figure 2)

A magnetic field is generated in a designated space using an electric wire coil. When an individual carrying a detection tag enters this space, the tag information is automatically transmitted wirelessly to the control room. As long as the individual remains within the space, the information continues to be transmitted. Once they leave the space, the transmission stops, enabling real-time tracking of when and where each person is present. Additionally, the system is designed to automatically save the records in an Excel file.

Visually impaired individuals tested the system and provided positive feedback, stating that it ensures their safety and reassures them that people around them can also look out for their well-being. Moving forward, we believe this technology represents a significant step toward practical implementation.

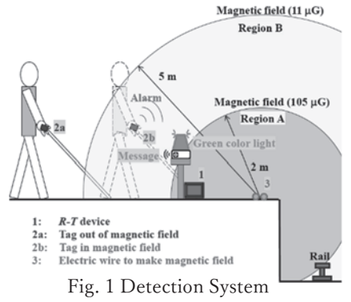

Fig. 1 Detection System

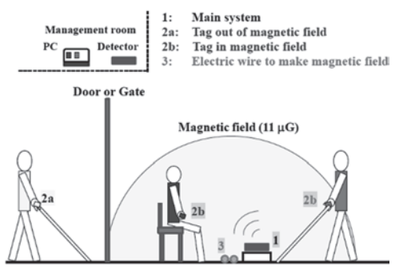

Fig. 2 Management

テレマティクスデータを活用した運転者特性に基づく安全経路推薦システムの構築

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本研究では、事故が起こりにくい安全な走行経路を機械学習によって推薦するシステムにおいて、目的地までの到着時間や走行距離の考慮を目的とした。

研究代表者らは機械学習によって運転者の特性を把握し、事故が起こりにくい安全な経路の推薦手法を提案している（Fukatsu, 2023）。先行研究（Fukatsu, 2023）では、各道路区間を過去に走行した運転者の情報と経路推薦対象の運転者の情報をテレマティクスデータから取得し、機械学習により推定される危険度（事故発生率）が最小の経路を推薦する。しかし、実際の移動では安全性だけでなく、目的地までの時間や走行距離に制約のある場合が多い。そのため、本研究では目的地までの到着時間や走行距離の制約を満たしつつ、最も安全な経路の推薦を進化的計算によって実現した。進化的計算は生物の進化の過程を模した組合せ最適化アルゴリズムで、遺伝的アルゴリズム（GA）や群知能などがある。制約条件として複数の要素を考慮した経路選択が可能なため、目的地までの距離や時間にしきい値を設定できる。複数の制約条件を考慮しつつ、運転者ごとに最も安全な経路を現実的な時間で探索可能なシステムの実現において、本研究の独創性と意義がある。実際のテレマティクスデータをもとに福井市内の一部の主要道路で危険度を推定し、OpenStreetMap 上に表示した例を図 1 に示す。

本研究では、提案する仕組みの実現・事業化のために必要なデータ収集にも貢献した。研究代表者と所属学生を含む合計 5 名は損害保険会社が令和 6 年 10 月 1 日から 10 月 31 日に福井県と開催した安全エコドライブコンテストに参加し（福井県, 2024)、データ収集に貢献した。今回のコンテストで収集されたデータは「交通安全マップ 2024」としても一般に公開されている。

図 1：福井市内における危険度の推定

今後の展望として、大規模な道路へ適用するため、計算量および実行時間の削減が考えられる。

主な成果

[1] 鄭 浩, 川上朋也, 川本義海, "テレマティクスデータからの道路特性に基づく安全な配送計画システムの評価," 情報処理学会研究報告, Vol. 2024-ITS-97, No. 14, pp. 1-7, 2024.
[2] H. Tei, T. Kawakami, and Y. Kawamoto, "A Safe Vehicle Routing System Based on Road Characteristics from Telematics Data," Proc. IEEE COMPSAC 2024 Workshops, pp. 1732-1737, 2024.

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- H. Fukatsu *et al.*, 2023, "A GA-Based Safe Route Recommendation Method Based on Driver Characteristics," Proc. IEEE COMPSAC 2023 Workshops, pp. 1279-1284.
- 福井県, 2024, "「第 2 回事業所対抗 安全エコドライブコンテスト」の表彰式・交通安全マップ贈呈を行います！," 福井県報道発表資料.

Construction of a Safe Route Recommendation System Based on Driver Characteristics Utilizing Telematics Data

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This research aimed to consider arrival time and driving distance in a system that uses machine learning to recommend safe driving routes.

We have proposed a method of recommending safe routes that are less likely to cause accidents by understanding driver characteristics through machine learning (Fukatsu, 2023). In the previous study, information on drivers who have traveled each road segment in the past and information on the target drivers of recommendation are obtained from telematics data, and routes with the least risk (accident rate) estimated are recommended using machine learning. However, in actual travel, there are often restrictions not only on safety, but also on the time and distance to the destination. Therefore, this research uses evolutionary computation to recommend the safest route while satisfying the constraints of arrival time and driving distance to the destination such as genetic algorithms (GAs). Route selection can take into account multiple factors as constraints, and thresholds can be set for distance and time to destination. The originality and significance of this research lies in the realization of a system that can search for the safest route for each driver in a realistic amount of time while considering multiple constraints. Figure 1 shows an example of how risks are estimated on a part of major roads in Fukui based on actual telematics data and displayed on OpenStreetMap.

This research also contributed to the collection of data necessary for the realization and commercialization of the proposed mechanism. We participated in a safe eco-driving contest held by a non-life insurance company with Fukui Prefecture in October 2024. The data is also available as "Traffic Safety Map 2024."

Figure 1: Estimated risks in Fukui.

Future issues include reducing the amount of computation and execution time for large roads.

Main Results

[1] H. Tei, T. Kawakami, and Y. Kawamoto, "A Study of a Safe Vehicle Routing System Based on Road Characteristics from Telematics Data," IPSJ SIG Technical Report, Vol. 2024-ITS-97, No. 14, pp. 1-7, 2024 (in Japanese).
[2] H. Tei, T. Kawakami, and Y. Kawamoto, "A Safe Vehicle Routing System Based on Road Characteristics from Telematics Data," Proc. IEEE COMPSAC 2024 Workshops, pp. 1732-1737, 2024.

References

- H. Fukatsu *et al.*, 2023, "A GA-Based Safe Route Recommendation Method Based on Driver Characteristics," Proc. IEEE COMPSAC 2023 Workshops, pp. 1279-1284.

情報・通信技術の応用：途上国・医療過疎地でも眼科診療を可能とするスマホ眼科医療機器を用いた、新しい眼科診療の開発と実用化

清水　映輔
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慶應義塾大学病院では、スマートフォンを用いた眼科診療デバイス「Smart Eye Camera（SEC）」を活用した臨床研究を国内外で積極的に進めています。SEC はスマートフォンに装着することで高精度な前眼部の画像を取得できる革新的な診療ツールであり、これまで医療機関内でしか行えなかった眼科診察を、患者の自宅や地域でも実施できる可能性を広げるものです。

2024 年度は、特に分散型臨床試験（Decentralized Clinical Trial: DCT）における SEC の実用性について検証を行いました。従来の治験においては、頻繁な通院が患者にとって大きな負担となっており、また、地理的制約による参加困難も課題とされてきました。そこで、当院では抗がん剤治療を受ける患者に対して、眼の副作用をモニタリングする目的で SEC を導入。患者自身が自宅で画像を撮影し、遠隔で専門医が解析する体制を構築しました。その結果、病院受診回数の削減、医師の診療負担の軽減、異常所見の早期発見など、多方面での有効性が確認されました。さらに、当院の国際医療連携部門と連携し、東南アジアやアフリカ諸国における SEC 活用の可能性についても実地調査を通じて検討を進めました。医療インフラが不十分な地域においても、安定した画像取得が可能であり、眼科専門医が不足する現場における遠隔診療支援ツールとして高い評価を得ています。

また、SEC により撮影された画像データと人工知能（AI）による解析技術を組み合わせることで、角膜混濁やドライアイ、白内障などの早期診断精度が大幅に向上することも明らかとなっています。AI を活用することで、診療の均てん化や医療資源の最適化に資する仕組みとして、今後の社会実装が期待されています。

これらの成果は、学会発表や査読付き論文として国内外に発信しており、眼科領域における新たな診療モデルの構築に貢献しています。今後も研究と臨床の両輪を通じて、すべての患者に質の高い眼科医療を届けることを目指し、技術革新と現場ニーズの統合を進めてまいります。さらに、教育機関として医療従事者の育成にも力を入れ、次世代のデジタル医療を支える人材の育成にも積極的に取り組んでいます。

Application of Information and Communication Technology: Development and Implementation of a Novel Ophthalmic Care Model Using Smartphone-Based Devices to Enable Eye Care in Low-Resource and Medically Underserved Settings

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Project Associate Professor, Keio University

Keio University Hospital has been actively promoting clinical research using the smartphone-based ophthalmic diagnostic device known as the Smart Eye Camera (SEC), both domestically and internationally. The SEC is an innovative tool that can be attached to a smartphone to capture high-resolution images of the anterior segment of the eye. This enables eye examinations that were traditionally limited to hospitals to be performed remotely, including in patients' homes and local communities.

In 2024, particular focus was placed on evaluating the utility of SEC in decentralized clinical trials (DCTs). In conventional clinical trials, frequent hospital visits often place a significant burden on patients, and geographical limitations can prevent participation. To address these challenges, SEC was introduced as a tool for monitoring ocular side effects in cancer patients undergoing chemotherapy. Patients used SEC to capture eye images at home, which were then remotely analyzed by ophthalmologists. This model resulted in a reduction in the number of hospital visits, decreased physician workload, and allowed for earlier detection of abnormalities, thereby demonstrating the practical value of the device in clinical settings.

In addition, collaboration with the hospital's global health department enabled field research in Southeast Asia and Africa, where the feasibility of using SEC in areas with limited medical infrastructure was explored. Even in such resource-limited settings, the device provided stable imaging results and received high praise as a telemedicine support tool in regions facing shortages of ophthalmic specialists.

Furthermore, combining the image data captured with SEC and artificial intelligence (AI)-based image analysis significantly improved early diagnostic accuracy for conditions such as corneal opacity, dry eye, and cataracts. By integrating AI technologies, SEC has shown great promise for equalizing the quality of care and optimizing limited medical resources, raising expectations for its widespread social implementation in the near future.

These research outcomes have been shared both in academic conferences and through peer-reviewed journal publications, contributing to the development of new ophthalmic care models. The SEC initiative also reflects a broader institutional commitment to fostering the next generation of healthcare professionals. As a teaching hospital, Keio University Hospital is committed not only to technological innovation but also to educating clinicians who can lead the future of digital medicine.

Moving forward, continued efforts will focus on integrating research and clinical practice to deliver high-quality ophthalmic care to all patients. By aligning cutting-edge technology with on-the-ground needs, the aim is to further advance medical solutions that are accessible, efficient, and impactful in both local and global healthcare environments.

アフターコロナにおけるパンデミックを阻止する IoT デバイスを通じた予防接種オファーに基づく新興感染症のダイナミック制御

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1. 序論

私たちがコロナ禍で経験した最大の教訓は、現代社会システムの安全安心を脅かす脅威として世界規模での新興感染症流行をいかにして未然に防ぎ、不幸にして感染拡大した場合には如何にして制御するのかを社会災害の観点から考究すべき点にあろう。COVID-19 パンデミックに同期して社会物理学では数理疫学と(例えば、有償ワクチン接種に関する)人間意思決定ダイナミクスとを統合した枠組み Vaccination Game (VG) への関心が高まっている[1], [2]。確率共鳴は統計物理学上のテーマだが、数理疫学モデルにおいてはワクチン接種情報を IoT デバイスにより広宣する際の確率揺らぎの効果に相当する[3]。確率共鳴の本義を考えると、エージェントが複雑ネットワークで接続される状況下を前提にすること、更には Perc[4]や Tanimoto[5] が発見した空間型囚人ジレンマゲームの利得行列への additive ノイズがネットワーク互恵を強化する現象とのアナロジーから想起して、背後に、所謂、ワクチン接種ジレンマが埋め込まれた VG に適用することは、興味ある研究課題である。本研究は、これに Multi Agent Simulation (MAS) を用いてアプローチする。

2. モデル

2.1.Vaccination Game (VG)

[2]の基本形を踏襲した[1]の VG を用いる。ワクチンの確率性は Effectiveness[1]に従う。すなわちワクチン接種イベントにおいてワクチン接種を行うエージェントは Effectiveness; Eにより完全免疫を獲得する。1 流行期は 2 ステージからなり、ステージ 1 で各エージェントは前流行期の自己利得とランダム選択した隣人利得との差異に基づく確率戦略更新 (PW-Fermi に基づく IB-RA[1]) をし、ステージ 2 で初期感染者 $I_0(=5)$ を粒子数 10^4、平均次数 ($\langle k \rangle$) 8 の BA-SF[6]上にランダム配置して当該流行期の SIR 感染ダイナミクスを感染者 I がいなくなるまで Gillespie 法により追跡する。ワクチン接種率 (VC) と最終感染者サイズ (FES) が社会均衡に達するまで流行期を繰り返し、MAS の結果としては 100 アンサンブル平均を採る。

2.2. 感染率に印加するノイズ

基本再生産数R_0=2.5、回復率γ =1/3[day^{-1}]として求まるリンクベース感染率$\beta_{eq} = \beta/\langle k \rangle = R_0 \cdot \gamma/\langle k \rangle$[7]に対し、各時間ステップ各リンクで上下限$\pm\delta$の一様乱数を付加する ($\beta_{eq} \pm \delta$)。

3. 結果及び考察

数値実験では感染時の疾病総コスト 1 に対する相対ワクチン接種コスト C_r ($0 \le C_r \le 1$) とワクチンの確率的有効性 E ($0 \le E \le 1$) を変えながら VC と FES を求める。$\delta = 0$のデフォルト設定に対してδの影響を考察する。Fig.1 に結果を示す。1 行目左パネルが VC、右パネルが FES のデフォルト設定の絶対値であり、これらは既往研究で報告されている結果[1]と一致する。2 および 3 行目は、夫々、大小のノイズを印加したときのデフォルト設定との差画像で、赤がプラス、青がマイナス偏差を意味する。SF グラフ上のワクチン接種がない単純な SIR プロセスに対して、感染率に additive ノイズを印加すると、感染力 (基本再生産数) の強さに依存への依存性が観察されるが、確率揺らぎがパーコレーション経路の連続性を棄損することで、最終感染サイズが小さくなる側へ deflate する (結果は示していない)。このことは揺らぎ幅が小さい範囲では VG にあっては有意な差異とはならない (Fig.1 の 2 行目)。而して、ノイズ幅が大きくなると (3 行目)、確率共鳴効果は大きく 2 相のパラメータ領域に分かれて発現する。ワクチンの信頼性が低く、コストが高い領域では、元々、デフォルト設定で VC=0 であるから、VC に差異は現れない。が、FES は小さい側に歪む (右下パネル)。一方、ワクチンが低コストで信頼性が比較的高い領域では、確率共鳴により感染リスクが低減されることが、エージェントをミスリードし、VC は低い側に歪み (3 行目左パネル)、これに依り FES は高い側に歪んでしまう (3 行目右パネル)。

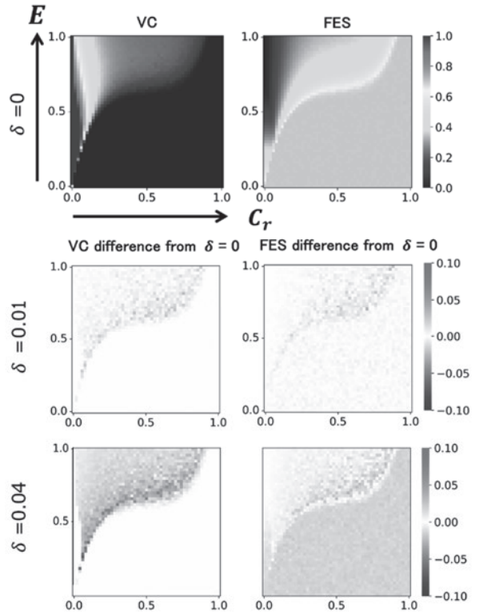

Fig.1　$\delta = 0$ の行にて、左図からワクチン接種率(VC)、最終感染者サイズ(FES)を示す。δ=0.01、0.04 の各行は、左図から δ=0 と比較した時の VC、FES の変化量を示す。

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Dynamic Control for Avoiding Pandemic of New-Emerging Epidemic by Social Information System to Offer Vaccination through IoT Devices in After-Corona Era

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The pandemic of COVID-19 makes us learn that a new emerging epidemic is the most serious risk to our modern world-wide community. As we know, the information spread by media and through the virtual community, about commitment vaccination for instance, inevitably entails a probabilistic fluctuation that deeply relates to the so-called stochastic resonance effect.

This study investigates a standard vaccination game presuming the repeated-season framework, in which we mutually merge the dynamics of disease spread, which obeys the SIR process, and human decision-making as regards whether or not to get vaccinated at the beginning of each season with reference to the evolutionary game theory. We herein presume the Barabási–Albert scale-free (BA-SF) graph as an underlying network. Accordingly, we explore whether or not an additive noise to the transmission rate brings an advantageous stochastic resonance effect for confining a disease's spread. The results show that with a higher vaccination cost and/or a lower vaccine efficacy, the stochastic noise has no gap in vaccination coverage (VC) with the default without noise case, but brings a smaller final epidemic size (FES). In contrast, at a lower vaccination cost and a higher vaccine efficacy, the additive stochastic noise brings a smaller VC that consequently results in a larger FES than the default without noise case. This phenomenon is completely different from our previously reported bolstered enhancement effect of network reciprocity, in which each element of a payoff matrix is exposed to stochastic noise.

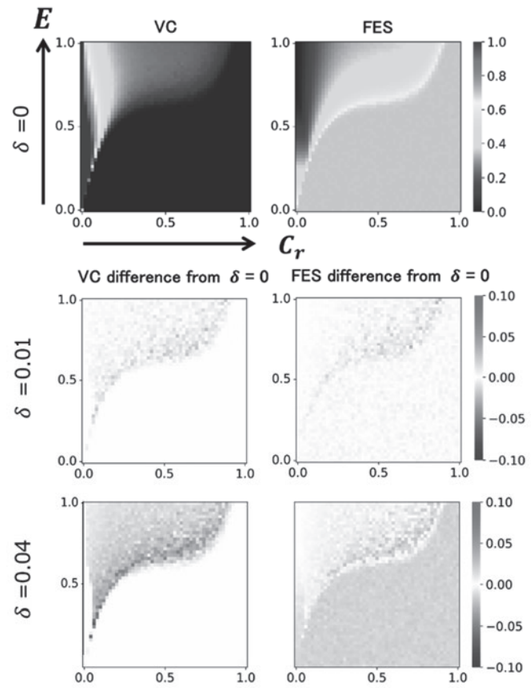

Figure 1:　The left column delivers heat-maps of vaccination coverage (VC) and the right one brings ones of final epidemic size (FES) along the relative vaccination cost to the disease cost (denoted by *Cr*) and the vaccination effectiveness (denoted by *E*). *d* represents the extent of stochastic resonance strength. The top row delivers the absolute value of VC and FES, respectively, while the middle and bottom rows bring the difference of VC and FES from the cases with $d = 0$, respectively.

誤情報拡散における責任感の成立機序に関する研究

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研究目的

近年，誤情報拡散が深刻な社会問題となっている。本研究では，この誤情報拡散の抑制に資する知見を得るため，誤情報発信者の対処行動（例：訂正，削除，謝罪）を始発，維持させうる心理的要因として責任感（responsibility）に焦点を当て，(a) 誤情報拡散に対する責任感の特徴と，(b) 責任感の個人差を生起させる要因を解明し，(c) 責任感を維持，回復するための方法について，学校教育等で実行可能な形で提案することを目指した。

研究成果

現実に存在した誤情報拡散事例を参考に誤情報拡散評価課題を作成し，成人を対象とした複数の調査によって誤情報拡散後の責任感の特徴について検討した。その結果，参加者の多くは自分よりも他者の方が誤情報から影響を受けやすいと推定するにもかかわらず [2]，自分が発信した誤情報から影響を受けうる人の数（例．リポストした人の数や受信者数）が増えても責任感を強めるとは限らないことが示された [1]。その一方で，情報の話題が重大になるほど責任感は強まる傾向が示されたことから，SNS 使用者は誤情報の拡散範囲よりも，情報の内容（例．日常生活の話題か，健康や安全に関わる話題か）に応じて責任感を変化させる可能性が示された。

また，誤情報拡散への責任感の高さは，対処行動の必要性評価と正の関係にあることから，誤情報拡散を抑制するためには，責任感の喚起が重要であることが再確認された。そこで本研究では，誤情報拡散に対するリスク評価尺度 [4]，および責任の所在を評価する尺度を作成し（投稿中），責任感を規定する心理的要因についてアプローチする方法を構築した。

さらに並行して，誤情報拡散後の対処行動を促進する要因について検討した結果，誤情報拡散への責任感が低い発信者であったとしても，批判的思考態度が高ければ対処行動をとろうとする傾向が認められた [1]。責任感をもちにくい対象者に責任感をもつように促すことは容易ではないが，誤情報拡散の影響や問題の程度を分析的に考えるよう促し，批判的思考を活性化することは相対的に容易だといえる。そこで，高校生を対象に誤情報拡散評価課題を実施し，実際に批判的思考を活性化させることで責任感の低さが補償され，対処行動の必要性評価が高まるかどうかを検証した。この成果については現在論文としてまとめており，今後学会で公開するとともに，さらに実践的な指導方法へと発展させる予定である。

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Psychological Mechanisms of Responsibility in the Diffusion of Misinformation

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Background and Objectives

The spread of misinformation is a serious issue. This study explores the sense of responsibility as a psychological factor that can initiate and sustain corrective actions (e.g., corrections, deletion, and apologies) by those who disseminate misinformation. It also seeks to gain insights into mitigating misinformation spread. The objectives are to (a) elucidate the characteristics of responsibility in misinformation dissemination, (b) identify factors contributing to individual differences in responsibility, and (c) propose methods for eliciting a sense of responsibility.

Research Findings

An evaluation task for misinformation dissemination was developed, and multiple surveys targeting adults were conducted. Results showed that although most participants believed others were more susceptible to misinformation [2], they did not feel more responsible when their misinformation affected more individuals [1]. However, responsibility increased with the severity of the topic, suggesting that users adjust their sense of responsibility based more on the content than on dissemination extent. For example, they felt a stronger sense of responsibility for spreading misinformation about health and safety issues than everyday life topics. Furthermore, scales for assessing the risk of misinformation sharing [4] and the locus of responsibility were developed to measure the individual difference factors that elicit a sense of responsibility.

Additionally, investigations have revealed that even those with low responsibility are more likely to take corrective action if they possess a critical thinking disposition [1]. While instilling responsibility in unresponsible individuals is challenging, encouraging analytical consideration of the issue's impact and severity, and activating critical thinking is more feasible. An evaluation task is being conducted with high school students to verify whether activating critical thinking can compensate for low responsibility and enhance the evaluation of corrective actions' necessity. These findings are being compiled into a manuscript for academic conferences and further refined for practical instructional methods.

Research Achievements

1. Kudo, H., & Onoda, R. (2024). Effect of critical thinking disposition on misinformation correction mediated by responsibility for spreading misinformation. The 6th ICMET, Dec. 2024.
2. Kudo, H., & Onoda, R. (2024). Exploring the relationship between Web Third-Person Effect of misinformation and critical thinking disposition. Proceedings of the 22nd ICoME, 243-246, Aug. 2024.
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ネット上の他者の反応が偽情報・誤情報訂正記事の効果に与える影響について

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ネット上の誤情報・偽情報対策として、訂正情報（警告ラベル、訂正記事）が出されている。ただ、訂正情報はネット上で広がる過程で、コメントやいいねといった他者の反応が付く。こうした他者の反応が訂正情報の効果に与える影響を探るため、本研究では、3 つの実験を実施した。

実験方法の概要

実験 1：他者コメントの内容（賛同 vs. 批判 vs. 混合）が警告ラベルの効果に与える影響を探った。18 歳~60 歳 1193 名（最終分析数 1044 名）を対象に、オンライン実験を実施した。

実験 2：ニュース投稿を見る際の視線の動きを分析することで、警告ラベルと他者反応の効果を探った。大学生 70 名（最終分析数 63 名）を対象にアイトラッキング実験を行った。

実験 3：批判的な他者コメントと、そのコメントに付くいいね数が、訂正記事の効果に与える影響を検討した。18 歳~70 歳 856 名（最終分析数 742 名）に対して、オンライン実験を実施した。

実験 1 と 3 では、参加者をランダムに異なる条件に振り分けた後、刺激（ニュース記事、警告ラベル、訂正記事、他者のコメント、いいね数）を提示し、記事に対する信憑性を図る質問（最低値 1、最高値 5）に回答してもらった。条件によって信憑性への回答がどのように異なるかを分析した。また、参加者の年齢やコメント参考経験も分析に加えた。

実験 2 では、警告ラベルの有無によって、ニュース投稿に付く他人の反応（いいね数やコメント数など）にどれだけ注目したかを測った。具体的には、何回見たか（訪問回数）、どれだけ見たか（注視時間）、どのタイミングで見たか（初めて見るまでの時間）の 3 つを測定し分析した。

結果と考察

まず、他者の反応、特に批判的なコメントはニュース信憑性を下げることがわかった。例えば実験 3 にて、批判的なコメントが付く群（M= 2.85）は付かない群（M= 3.01）に比べると記事の信憑性の値が有意に低くなった, $F(1, 738) = 4.21$, $p < .05$。実験 1 でも記事内容に対するコメントが批判的な群（M= 2.04）は他の 2 群（賛同群（M= 2.23）、混合群（M= 2.37））に比べて、記事の信憑性が有意に低かった, $F(7, 1036) = 10.10$, $p < .001$。

また、実験 3 の結果では、普段からニュース評価においてコメントの内容を参考にする人ほど、いいね数をもとに、記事の信憑性の判断を行いやすい傾向が見られた。さらに、本来であれば、訂正記事に対する批判的なコメントに、多数のいいねが付くことは、訂正記事の信憑性を下げることにつながる。しかし、若年層は逆に信憑性が上がる結果となった（図 1）。理由として、低年齢のうちからいいね数に触れている若年層は、「いいねが多い＝注目を集めている → 信じられる」と無意識的に判断した可能性が考えられる。

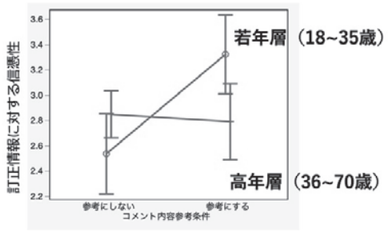

図 1: いいね数多条件における年齢層・コメント参考の交互作用

最後に、実験 1 と 2 の結果から、警告ラベルがあることで、他者コメントを参考にしにくくなることがわかった。ここから、ニュース信憑性を正す上で、警告ラベルは他者反応の影響を受けにくいことが示唆される。

Impact of Others' Reactions on Accessing the Credibility of News for Correcting Misinformation

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To fight mis- and dis-information, some media outlets public corrective information (i.e., corrective articles or warning labels) to caution audience. However, as corrective information spreads on the internet, it is often accompanied by reactions from others, such as comments and likes. This study conducted three experiment to examine how do others' reactions influence the effectiveness of corrective information.

Overview of Methods

Experiment 1: An online experiment with 1,193 participants aged 18 to 60 (final analysis included 1,044 participants) was conducted to explore the impact of the comment tone (supportive vs. critical vs. mixed) on the effectiveness of warning labels.
Experiment 2: An eye-tracking experiment with 70 university students was conducted to analyze the effect of warning label and number of likes.
Experiment 3: To investigate the impact of critical comments and the number of likes on corrective articles, an online experiment was conducted with 856 participants aged 18 to 70 (final analysis included 742 participants).
In Experiments 1 and 3, participants were randomly assigned to different conditions and were shown stimuli (news articles, warning labels, corrective articles, comments from others, and the number of likes). They were then asked to rate the credibility of the article on a scale of 1 (lowest) to 5 (highest). The differences in credibility ratings across conditions were analyzed, along with factors such as participants' age and prior experience in referring to comments.
In Experiment 2, the study measured the extent to which participants paid attention to others' reactions (such as the number of likes and comments) depending on the presence or absence of a warning label. Specifically, three aspects were analyzed: the number of times participants looked at the reactions (visit count), the duration of their gaze (fixation time), the timing of their first glance at the reactions (time until first fixation).

Results and Discussion

The current study found three major findings. First, critical comments reduce the perceived credibility of news articles. In Experiment 3, articles that received critical comments (M= 2.85) had significantly lower credibility scores compared to those without such comments (M = 3.01), $F(1, 738) = 4.21$, $p < .05$. Similarly, in Experiment 1, articles with critical comments (M= 2.04) were rated significantly less credible than those with supportive comments (M= 2.23) or mixed comments (M= 2.37), $F(7, 1036) = 10.10$, $p < .001$. Second, Experiment 3 showed that individuals who often refer to comments when assessing news credibility were more likely to use the number of likes on comments as a cue for evaluating the credibility of a corrective article. Normally, when a critical comment on a corrective article receives many likes, it would lead to a decrease in the article's credibility. However, for younger individuals, the opposite effect was observed, resulting in an increase in perceived credibility (Figure 1). One possible reason is that younger individuals, who have been exposed to "likes" on SNS from an early age, may made a subconsciously interpretation that "a high number of likes means gaining attention, and therefore it can be trusted.

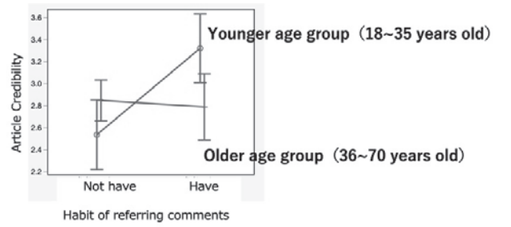

Figure 1: The interaction effect of age groups and habit of referring comments when the number of likes on comments is in high condition.

Finally, warning labels reduced reliance on others' comments. Findings from Experiments 1 and 2 indicated that the presence of warning labels made people less likely to rely on comments from others. This is likely because warning labels serve as an independent cue for assessing credibility, thereby reducing the influence of other users' comments.
This research highlights the significant role of social reactions, such as comments and likes, in shaping public perceptions of news credibility. It also suggests that warning labels can mitigate the influence of such reactions.

民事訴訟の IT 化に伴う訴訟記録管理における情報保護に関する研究

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本研究の目的は、社会全体における情報の電子化の流れの中で、訴訟記録の電子化が、理論上実務上どのような問題を生じさせる可能性があり、どのような指針に基づいて解決の方向性を見出すかを、明らかにすることである。

この研究課題については、約15年間にわたって、主に、訴訟記録中に含まれる当事者ないし関係者の個人情報の取扱が、果たして他の公的機関における取扱いと比べて妥当な範囲に収まっているものであるか否か、全ての情報を権利として取得することが可能な立場にある当事者に対して、何らかの制約を課すことが可能であるか否か、という点を検討し続けてきたところ、その中で新たに生じてきた実務の変化が、今回の研究目的である訴訟記録の電子化という実務の変化であり、本研究は、上記研究課題における今後最も重要な論点となることが予測される。

もっとも、研究成果である下記論文を参照すれば明らかなとおり、本研究で指摘している実務上の問題点の多くは、立法により一定の解決を導くことが可能な、いわゆる技術的問題点が多数を占めているが、かかる技術的問題点の解決においても理論的な一貫性妥当性が必要であることは明らかであり、本研究の意義は、将来において、実務上の解決について議論が分かれ、あるいは想定されていなかった問題点が生じてきた場合における、解決の方向性を具体的に示唆する効果を持つことが期待できるものである。

長期的に見て、訴訟記録が全て電子化され、原則として紙を使用しない運用は必ず達成されるものと思われるが、裁判実務は現に係属中の案件に対処し続ける必要があり、かつ、裁判所を含めた実務家の意識を電子化に適応させるまでには、場合によっては数十年単位の時間が必要となることが予測される（特許出願が実務上完全に電子化されるに到るまでには、約 30 年近くかかっている）。

また、裁判や裁判所の文化的な地位、すなわち、各地域の法的権威と統治機構の重要部分を統治者が独占し、民主主義とは異なる観点からの官僚体制によって実務の大部分を運用するという性格が、今後における社会全体の電子化の傾向の中でどのように変化していくこととなるかは、本研究の今後の課題として最も重要な点であり、さらに、電子化による隠れた実務上の効果として、ある観点からの世代交代の促進を加速するということが訴訟を中心とする法律実務に対してどのような影響を与えていくこととなるかも、興味深い論点ということができる。

以上のとおり、本研究から先の検討対象としては、訴訟記録のみならず、「裁判所自体の電子化」についても、研究の対象を拡げていく必要があるものと思われる。

【今回の研究成果】
・星野豊「訴訟記録の電子化に伴う問題状況の整理と解決の方向性」筑波法政 94 号 21-30 頁（2025 年 3 月）　http://hdl.handle.net/2241/0002014413

【参考・本研究前の関連成果】
・星野豊「訴訟記録の閲覧制限と当事者の配慮義務」末川民事法研究 10 号 39-52 頁（2023 年 10 月）　http://hdl.handle.net/2241/0002009851
・星野豊「民事訴訟記録の閲覧制限と当事者の秘密保護の実効性」末川民事法研究 1 号 1−11 頁（2017 年 10 月）　http://hdl.handle.net/2241/00151737
・星野豊「民事訴訟記録における個人情報の取扱に関する一考察」筑波法政 49 号 1-21 頁（2010 年 9 月）　http://hdl.handle.net/2241/114572

Research on Information Protection in Lawsuit Record Management Associated with the Use of IT in Civil Lawsuits

Yutaka Hoshino
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The purpose of this study is to clarify what problems the digitization of litigation records may give rise to, both in theory and in practice, within the trend toward digitization of information throughout society, and what guidelines should be used to find a solution.

Approximately 15 years, I have been mainly focusing on whether the handling of personal information contained in litigation records is within reasonable range compared to other public institutions, and whether it is possible to impose any restrictions on the parties, having all information as their rights. In these researches, the computerization of litigation records should be new change in practice, will be the main subject of this research. I expect that this research will become the most important point of discussion in the future for the above research topic.

Although many of the practical issues pointed out in this research are so-called technical ones that should be solved through practice, theoretical viewpoints are also necessary to resolve such issues. The significance of this research is that it can be expected to have the effect of providing suggestions in the future problems, when there are divided opinions or unanticipated.

It will be expected that all litigation records will be all digitized, paper-free operation will be achieved, but court practice will need to continue to deal with cases currently pending, so it will may take decades for practitioners, including the courts, to adapt to the shift to digitization (it took nearly 30 years for patent applications to be completely digitized in practice).

The most important future challenge for this research is how the cultural status of trials and courts, the nature of each region's legal authority, important parts of its governing institutions being monopolized by its rulers, and main practical work being carried out by bureaucratic system, will change in the future trend toward computerization of whole society. Furthermore, one interesting point of discussion will be how the hidden practical effect of computerization, in the form of accelerating the promotion of generational change, will affect legal practice.

As described above, it seems necessary to expand the scope of research beyond this study to include not only litigation records but also the "digitization of the courts themselves."

[Research Results]
・Yutaka Hoshino, Current Issues and Solutions as to Digitalized Records of Litigations, Tsukuba Journal of Law & Politics, No. 94, pp. 21-30 (March 2025)
http://hdl.handle.net/2241/0002014413

[Reference: Related Results Prior to This Research]
・Yutaka Hoshino, Restrictions on Viewing Records of Civil Cases and Duty of Parties to Care, Suekawa Civil Law Study, Vol. 10, pp. 39-52 (October 2023)
http://hdl.handle.net/2241/0002009851
・Yutaka Hoshino, Effective Protection for the Secrets of the Parties by Restriction in Public Perusal for the Records of the Civil Cases, Suekawa Civil Law Study, Vol. 1, pp. 1-11 (October 2017)
http://hdl.handle.net/2241/00151737
・Yutaka Hoshino, Problems of Personal Information in Civil Case Documents, Tsukuba Journal of Law & Politics, No. 49, pp. 1-21 (September 2010)
http://hdl.handle.net/2241/114572

Towards Scalable Decentralized Databases

Natacha Crooks
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The research funded by the grant was published at SOSP'24, the systems' premier conference venue.

Today's practical, high performance Byzantine Fault Tolerant (BFT) consensus protocols operate in the partial synchrony model. However, existing protocols are inefficient when deployments are indeed partially synchronous. They deliver either low latency during faultfree, synchronous periods (good intervals) or robust recovery from events that interrupt progress (blips). At one end, traditional, view-based BFT protocols optimize for latency during good intervals, but, when blips occur, can suffer from performance degradation (hangovers) that can last beyond the return of a good interval.

At the other end, modern DAG-based BFT protocols recover more gracefully from blips, but exhibit lackluster latency during good intervals. To close the gap, this work presents Autobahn, a novel high-throughput BFT protocol that offers both low latency and seamless recovery from blips. By combining a highly parallel asynchronous data dissemination layer with a low-latency, partially synchronous consensus mechanism, Autobahn (*i*) avoids the hangovers incurred by traditional BFT protocols and (*ii*) matches the throughput of state of the art DAG-based BFT protocols while cutting their latency in half, matching the latency of traditional BFT protocols.

Generality and Dexterity in Visuomotor Control

Chelsea Finn
Assistant Professor, Stanford University

One of the key arguments for building robots that have similar form factors to human beings is that we can leverage the massive human data for training. Yet, doing so has remained challenging in practice due to the complexities in humanoid perception and control, lingering physical gaps between humanoids and humans in morphologies and actuation, and lack of a data pipeline for humanoids to learn autonomous skills from egocentric vision. In our research, we introduce a full-stack system for humanoids to learn motion and autonomous skills from human data. We first train a low-level policy in simulation via reinforcement learning using existing 40-hour human motion datasets. This policy transfers to the real world and allows humanoid robots to follow human body and hand motion in real time using only a RGB camera, i.e. shadowing. Through shadowing, human operators can teleoperate humanoids to collect whole-body data for learning different tasks in the real world. Using the data collected, we then perform supervised behavior cloning to train skill policies using egocentric vision, allowing humanoids to complete different tasks autonomously by imitating human skills. We demonstrate the system on our customized 33-DoF 180cm humanoid, autonomously completing tasks such as wearing a shoe to stand up and walk, unloading objects from warehouse racks, folding a sweatshirt, rearranging objects, typing, and greeting another robot with 60-100% success rates using up to 40 demonstrations.

Detecting and Reducing Hallucination of Generative Language Models

Nanyun Peng
Associate Professor, University of California, Los Angeles

Large pretrained language models (LLMs) have revolutionized the areas of natural language generation (NLG) by producing astonishing high-quality texts. While the models have demonstrated impressive capability, how to evaluate the generation results becomes an open challenge. Especially, it is widely noticed that LLMs tend to hallucinate, which means they generate plausible-sounding but factually incorrect or unverifiable content. However, it is challenging to automatically identify such hallucinations, let alone reduce them. The goal of this research proposal is to explore a transformative direction of building automatic evaluation metrics to detect hallucination of LLMs. The research results in several benchmarks and computational approaches for detecting and reducing hallucination in LLMs-generated texts that can benefit a wide range of NLG applications, such as text summarization, image captioning, and open-domain text generation. Under the support of this Okawa Research Grant, we published three papers in top-tier artificial intelligence (AI)/machine learning (ML) and natural language processing (NLP) venues, including 1) Paper titled "Open-Domain Text Evaluation via Contrastive Distribution Methods" with authors: Sidi Lu, Hongyi Liu, Asli Celikyilmaz, Tianlu Wang, Nanyun Peng, published at ICML 2024 (The Forty-First International Conference on Machine Learning), 2) Paper titled: "VALOR-Eval: Holistic Coverage and Faithfulness Evaluation of Large Vision-Language Models" with authors: Haoyi Qiu, Wenbo Hu, Zi-Yi Dou, Nanyun Peng, published at ACL-Findings 2024 (Findings of the Association for Computational Linguistics: The 62nd Annual Meeting of the Association for Computational Linguistics), and 3) Paper titled: "AMRFact: Enhancing Summarization Factuality Evaluation with AMR-Driven Negative Samples Generation" with authors: Haoyi Qiu, Kung-Hsiang Huang, Jingnong Qu, Nanyun Peng, published at NAACL 2024 (2024 Annual Conference of the Nations of the Americas Chapter of the Association for Computational Linguistics).

Building NLP Systems with Generality and Common Sense

Xiang Ren
Associate Professor, University of Southern California

My research, as supported by Okawa Foundation, aims to advance commonsense reasoning in natural language processing (NLP) by systematically addressing its core challenges through three integrated thrusts: evaluation, modeling, and reliability. We develop new evaluation paradigms that stress-test language models on complex reasoning tasks, including lifelong multi-task learning, theory-of-mind inference, logical rule application, inductive hypothesis refinement, and long-tail knowledge verification. These evaluations reveal persistent failure modes in today's leading models—such as distraction from irrelevant context, difficulty connecting beliefs to actions, and overreliance on brittle surface cues.

To address these limitations, we design novel model-centric and algorithmic solutions. Our frameworks—such as SELF-DISCOVER and logic scaffolding—enable models to dynamically compose reasoning strategies or leverage external rule-based engines for more structured, interpretable reasoning. We also demonstrate the effectiveness of prompting innovations like Foresee and Reflect, and lightweight fine-tuning approaches that produce smaller yet competitive reasoning modules. These methods consistently improve performance across a variety of challenging benchmarks. Equally crucial to our agenda is enhancing the robustness and trustworthiness of NLP systems. We investigate how models express uncertainty, compare their inference behaviors to humans, and evaluate their ability to self-rationalize with faithful explanations. Our findings highlight concerning overconfidence biases stemming from training signals and propose concrete interventions, such as multi-reward optimization and entailment-based reasoning filters, to produce more reliable outputs.

Together, this line of work contributes a cohesive vision for building NLP systems that not only perform complex reasoning but also do so transparently and safely. By uniting rigorous evaluation, model innovation, and reliability analysis, we lay the foundation for AI systems that are better aligned with human reasoning and better suited for deployment in high-stakes, real-world environments.

Towards Robust Video Streaming over Next Generation Mobile Networks

Feng Qian
Associate Professor, University of Southern California

This project consists of three research tasks on improving multimedia content delivery over mobile networks. First, we conduct an in-depth study of bandwidth allocation across multiple media sources in video conferencing applications (VCAs). We analyze bandwidth allocation strategies in Zoom, Webex, and Google Meet, with a focus on QoE implications. To assess QoE, we propose a general QoE prediction model based on data collected from a study involving 800 participants. The results demonstrate the model's effectiveness and generality in predicting QoE across various VCA scenarios. Second, we develop a dynamic Time Division Duplex (TDD) mechanism for 5G/xG networks and demonstrate how to use it to improve video streaming performance. In the era of 5G and beyond, TDD has become essential for supporting applications that demand high bandwidth and low latency. We introduce Wixor, a robust dynamic TDD policy adaptation system tailored for 5G/xG networks. It proactively adjusts the allocation of TDD resources between uplink and downlink, addressing various practical challenges. Prototyped on a programmable testbed, Wixor demonstrates substantial performance improvements across diverse applications, achieving up to 96.5% enhancement in Quality of Experience (QoE) compared to existing baselines. Third, we design a framework that uses full-body pose tracking and multipath networking to boost mobile immersive content delivery over millimeter-wave (mmWave) wireless networks. Delivering immersive content such as volumetric videos and virtual/mixed reality requires tremendous network bandwidth. mmWave radios such as 802.11ad/ay and mmWave 5G can provide multi-Gbps peak bandwidth, making them good candidates. In this research, we investigate two under-explored dimensions. First, we use the combination of a viewer's full-body pose and the network information to predict mmWave performance as the viewer exercises six-degree-of-freedom (6-DoF) motion. Second, we jointly use the omnidirectional radio and mmWave radio available on commodity mobile devices to deliver immersive data. We integrate the above two features into a user-space software framework called Habitus, and demonstrate how it can be easily integrated into existing immersive content delivery systems to boost their network performance and QoE.

Evolving Stability in a Multispecies Network

Joseph Parker
Professor, California Institute of Technology

Insect diversification has been catalyzed by widespread specialization on novel hosts—a process underlying exceptional radiations of phytophagous beetles, lepidopterans, parasitoid wasps, and inordinate lineages of symbionts, predators and other trophic specialists. The strict fidelity of many such interspecies associations is posited to hinge on sensory tuning to host-derived cues, a model supported by studies of neural function in host-specific model species. Here, we investigated the sensory basis of symbiotic interactions between a myrmecophile rove beetle and its single, natural host ant species. We show that host cues trigger analogous behaviors in both ant and symbiont. Cuticular hydrocarbons—the ant's nestmate recognition pheromones—elicit partner recognition by the beetle and execution of ant grooming behavior, integrating the beetle into the colony via chemical mimicry. The beetle also follows host trail pheromones, permitting inter-colony dispersal. Remarkably, the rove beetle also performs its symbiotic behaviors with non-host ants separated by ~95 million years, and shows minimal preference for its natural host over non-host ants. Experimentally validated agent-based modeling supports a scenario in which specificity is enforced by physiological constraints on symbiont dispersal, and negative fitness interactions with alternative hosts, rather than via sensory tuning. Enforced specificity may be a pervasive mechanism of host range restriction of specialists embedded within host niches. Chance realization of latent compatibilities with alternative hosts may facilitate host switching, enabling deep-time persistence of obligately symbiotic lineages.

Pragmatic Language Interfaces: Modeling Human Users of Natural Language Processing Systems

Daniel Fried
Assistant Professor, Carnegie Mellon University

Our work this year has aimed to make it easier for people to use language to interact with computers to carry out real-world tasks. Advances in NLP and machine learning have laid a foundation for language interfaces, such as ChatGPT and Github's Copilot, that are used by millions of people to aid in a variety of computer-assisted tasks. However, the full potential and range of these systems are still untapped. The main goals of my work have been to make language interfaces more widely applicable and better collaborators with their human partners, and to develop new computational models of interaction inspired by human language and communication. Toward these goals, our work has covered three core areas.

Grounded language agents: To cover the full range of tasks that people would like to do with computers, language interfaces must extend beyond text. Our work on language grounding ties language to extra-linguistic modalities such as images, web pages, semi-structured data, and sequential actions or decisions in real-world environments. Grounding language in these ways enable people to carry out goals in contextually rich settings, using language and computers.

Interactive communication: Current language interfaces lack a variety of communicative abilities needed to make interactions with people efficient and consistently successful. To build interfaces that are easier to communicate with, we need to model linguistic pragmatics: tying language to context, conventions, and people's goals and likely interpretations. Our work models the human partners that NLP systems interact with, and shows that reasoning about these partners improves the ability to communicate pragmatically.

Code generation: Language interfaces for code generation have made programming more accessible to novices and more efficient for professionals. However, current interfaces still fall far short of the collaborative and communicative process of human pair programming. Our work has built models, benchmarks, and algorithms for language-based generation and refinement of program code.

Fine-Grained Visual Perception in the Wild

Shiliang Zhang
Associate Professor, Peking University

Under the topic of fine-grained visual perception in the wild, Shiliang Zhang has conducted research focusing on three aspects: compact neural network architectures, efficient deep learning methods, and methods for fine-grained visual perception in the last year. The main innovative achievements are summarized as follows:

(i) He proposed compact neural network architectures from the perspectives of information-preserving token fusion and Neural Architecture Search (NAS). Related work has been published in IEEE T-IP, ACM TOMM, and CVPR 2025. For instance, his CVPR 2025 work proposed a novel NAS algorithm. Graph Neural Networks (GNNs) and transformers have shown promising performance in representing neural architectures. However, each of them has its disadvantages. GNNs lack the capabilities to represent complicated features, while transformers face poor generalization when the depth of architecture grows. His work effectively mitigates the above issues, and proposes a novel predictor leveraging the strengths of GNNs and transformers. It consistently achieves promising performance in both neural network accuracy and latency prediction.

(ii) He proposed efficient deep learning methods from the perspectives of generalizable self-supervised learning, continual learning, learning from long-tail and noisy data, and collaborative learning between large and small models, effectively improving the training efficiency and stability of AI models and reducing the need for data annotation. Related work has been published in TPAMI, T-IP, IJCV, AAAI, CVPR. For example, his T-PAMI 2025 work proposed a novel self-supervised learning algorithm. Existing Masked Image Modeling methods apply fixed mask patterns to guide the self-supervised training. As those mask patterns resort to different criteria to depict image contents, sticking to a fixed pattern leads to a limited vision cues modeling capability. His work introduces an evolved hierarchical masking method. The proposed method leverages the vision model being trained to parse the input visual cues into a hierarchy structure, which is hence adopted to generate masks accordingly. It does not require extra pre-trained models or annotations and ensures training efficiency by evolving the training difficulty. Experimental results demonstrate that it substantially boosts performance across different tasks including image matching, classification, segmentation, etc.

(iii) He leveraged the strong generalization and reasoning capabilities of large AI models, and proposed generalizable visual perception methods. His methods significantly improved the performance of tasks such as fine-grained visual recognition, multimodal visual question answering, open-set object recognition, object pose and shape estimation, zero-shot recognition, and person re-identification. Related works have been published in T-PAMI, AAAI, CVPR, and have been submitted to ICCV 2025 and ICML 2025. For example, one of his CVPR 2025 work proposed an efficient method to build Multi-modal Large Language Models (MLLMs). It presents a new method for constructing the instruction tuning dataset at a low cost by leveraging annotations in existing datasets. A self-consistent bootstrapping method is also introduced to extend existing dense object annotations into high-quality referring-expression-bounding-box pairs. These methods enable the generation of high-quality instruction data which includes a wide range of fundamental abilities essential for fine-grained image perception. His MLLMs, which is named as Pink, exhibits a 5.2% accuracy improvement over Qwen-VL on GQA and surpasses the accuracy of Kosmos-2 by 24.7% on RefCOCO val. It also attained the top rank on the leaderboard of MMBench.

Data-Driven Software Security Analysis

Chao Zhang
Associate Professor, Tsinghua University

Software security analysis is crucial for protecting software and systems from attacks. Existing solutions are facing numerous bottlenecks, especially when analyzing programs without source code. Given that large language models (LLMs) have shown significant achievements in many language-related tasks. and programs are written in programming languages, we proposed to explore LLM-based solutions to analyze software, and understand programs' structures, semantics and eventually security properties. We expect to build the first comprehensive LLM solution for machine language and apply it to software security analysis tasks. Towards this goal, we have made some progress, covering topics including model training dataset construction, model designing, application to program semantic analysis (e.g., function name recovery), and application to security analysis tasks (e.g., vulnerability detection).

First, we proposed a novel solution to automatically generate training data. Specifically, we have built a neural network to simulate a compiler, which could compile a wide range of code to assembly and yield training data for training our machine language model. This work "Virtual Compiler Is All You Need For Assembly Code Search" is published in the top-tier conference ACL 2024.

Second, we proposed a contrastive language-assembly pre-training solution CLAP, which employs natural language supervision to make the model learn better representations of binary code and get better transferability. We have generated 195 million pairs of binary code and explanations and trained a machine language model (MLM). The evaluations of MLM across various downstream tasks in binary analysis all demonstrate exceptional performance. Notably, without any task-specific training (i.e., zero-shot), MLM is often competitive with a fully supervised baseline, showing excellent transferability. This work "CLAP: Learning Transferable Binary Code Representations with Natural Language Supervision" is published in the top-tier conference ISSTA 2024.

Third, we applied our model to various applications, including semantic analysis for binary programs, e.g., function name recovery. The results showed that, our model could help recover function names for binary programs and greatly help security analysts and reverse engineers. This work "llasm: Naming Functions in Binaries by Fusing Encoder-only and Decoder-only LLMs" is accepted by the top-tier journal TOSEM.

Lastly, we also applied our model to security analysis tasks, e.g., vulnerability discovery. Specifically, we utilized the LLM to analyze IoT devices' firmware (binary code) and analyze its routing mechanism, which determines how front-end user requests are dispatched to back-end handlers (e.g., functions or scripts). Then, the routing knowledge is used to facilitate fuzzing, i.e., the most popular vulnerability discovery solution, to find vulnerabilities related to hidden interfaces (i.e., user request APIs that are not disclosed or well tested). This work "EAGLEYE: Exposing Hidden Web Interfaces in IoT Devices via Routing Analysis" is published in the top-tier conference NDSS 2025.

Moreover, we have a lot of ongoing works, including refining the MLM model and applying MLM to downstream tasks. We believe it would lead to a significant success in this field.

For your information, attached is a copy of one of our published papers, entitled "CLAP: Learning Transferable Binary Code Representations with Natural Language Supervision" published in ISSTA 2024.[i] This paper presents some core designs of our machine language model MLM.

[i]https://dl.acm.org/doi/10.1145/3650212.3652145

Theory and Design of Low-Cost Compact Millimeter-Wave Phased Array Antenna for Mobile Phones

Yan Wang
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This research presents two innovative millimeter-wave (mmWave) array designs aimed at addressing the challenges of wide-angle scanning in compact mobile phone applications.

First, a compact four-element mmWave array with a small element spacing of 0.3-wavelength is developed to achieve wide-angle scanning from -60° to 60°. The primary challenges in designing such a compact array include the realization of a small-sized array element and effective mutual coupling reduction. To overcome these challenges, a modified quarter-wavelength shorted patch antenna element operating at 25.5-27.5 GHz is introduced. By incorporating a coupled shorted structure and a coupled feeding structure, the design significantly suppresses the H-plane cross-polarization level (XPL), which is a common drawback of quarter-wavelength shorted patch antennas. Additionally, to mitigate mutual coupling between elements, three compact neutralization lines (NLs) are implemented, ensuring that coupling remains below -15 dB. As a result, the proposed four-element array, occupying a minimal size of $1.14\lambda_0 \times 0.3\lambda_0$, is the smallest mmWave array of its kind reported in the literature. The array achieves a peak gain of 9 dBi, with minimal gain fluctuation (less than 1.3 dB), good sidelobe performance, and acceptable cross-polarization levels, making it a promising solution for next-generation mobile devices.

Building upon the concept of compact and wide-angle scanning arrays, a dual-band, dual-polarized stacked gridded patch array is also proposed for 5G mmWave applications. A key limitation in dual-band arrays is that the element spacing required for the lower frequency band often large in the higher band which will lead to constrained scanning capabilities. To address this, a novel sidelobe cancellation technique is introduced, incorporating two additional high-band elements to suppress high sidelobe levels and improve scanning performance. The dual-band element is designed using eigenmode theory and consists of a stacked patch with a gridded lower-band patch, covering the 24.25-29.5 GHz and 37-40 GHz frequency ranges. The additional higher-band elements employ a traditional stacked patch antenna design, ensuring efficient wide-angle scanning. The proposed array, constructed with a 1×4 dual-band element configuration and element spacings of $0.47\lambda_L$ in the lower band and attached two higher band elements, occupies a compact size of $2.3\lambda_L \times 0.4\lambda_L$. It achieves a scanning range of $\pm50°$ in the lower band and $\pm45°$ in the higher band for both H-pol and V-pol polarizations radiation.

Both proposed mmWave arrays, with their compact size, enhanced scanning range, and robust performance, offer promising solutions for next-generation mmWave mobile communication systems, particularly in 5G and beyond.

Research on Area- and Power-Efficient Silicon-Based Millimeter-Wave Phased-Array Transceivers Targeting Over 100Gbps

Jian Pang
Associate Professor, Shanghai Jiao Tong University

The millimeter-wave (mmW) spectrum with abundant spectrum resources becomes the key to the future wireless communications. To overcome the path loss in mmW frequencies, phased-array systems supporting beamforming are essential. In addition, with the development of semiconductor manufacturing process, silicon-based and compound-based phased-array transceiver chips for mmW wireless communications maintain the advantages of low cost and high integration level. They show great potentials for realizing wireless communication systems towards 100 Gbps.

However, the internal parasitic effects of silicon-based and compound-based devices have a significant influence in mmW frequencies, severely limiting the key performance of the devices. On the other hand, the limited antenna pitch in mmW phased-array systems also imposes stringent requirements on the size of multi-channel phased-array transceiver chips.

In this research, a W-band CMOS 4-element phased-array transceiver chip based on an area-efficient asymmetric bi-directional architecture is proposed. The introduced asymmetric bi-directional PA-LNA can be configured into PA mode or LNA mode. Therefore, complete same circuits including the passives along the transceiver channel, the division/combination network, the up/down-converter, and the LO generation network can be fully shared between TX and RX modes. The on-chip area for such phased-array transceiver can be reduced to half.

Additionally, asymmetric design is also applied to the proposed PA-LNA to satisfy the different requirements from TX and RX. The transistor size in TX mode is selected with larger size to improve the output power, while appropriate-sized transistors are selected in RX mode for noise matching. Therefore, improved overall TX and RX performance can be maintained with minimized chip area.

In measurement, the proposed W-band CMOS 4-element phased-array transceiver chip maintains a chip area of 3mm × 2mm, which is compact. The measured gain of better than 26 dB can be always realized in both TX and RX modes. The corresponding 3-dB bandwidth is from 89–98 GHz. In TX mode, the transceiver channel achieves a P_{sat} of 13.2 dBm and a PAE of 17.2% at 96 GHz. The measured NF is less than 9.4 dB across the 3-dB bandwidth. The proposed chip can support over 7-bit phase shifting and 4-bit amplitude tuning. The resulting phase and gain errors are both minimized during phase or gain tuning. For each transceiver channel, the power consumption in TX mode is 147 mW in saturation. The power consumption in RX mode is 45 mW.

This research also introduces a W-band GaAs transceiver front-end chip to improve the output power and suppress the noise of W-band phased-array systems. The proposed chip consists of a four-stage PA, a four-stage LNA, and a T/R switch. In measurement, over 25-dBm output power and less than 6-dB NF are realized by the proposed chip.

Interactive Cluster Examination in Multidimensional Views Using Distortion-Conscious Brushing

Jinwook Seo
Professor, Seoul National University

The research result has been submitted to IEEE Transactions on Visualization and Computer Graphics with the title of “ Distortion-aware Brushing for Reliable Cluster Analysis in Multidimensional Projections.” As of today, it is under review after major revision. Below is the abstract of the manuscript attached to this report as part of the result of this research grant.

Brushing is a typical interaction methodology in 2D scatterplots, allowing users to select clustered points within a continuous, enclosed region for further analysis or filtering. However, applying conventional brushing to 2D representations of multidimensional (MD) data, i.e., Multidimensional Projections (MDPs), can lead to unreliable cluster analysis. This unreliability stems from distortions that MDPs introduce, which makes them inaccurately represent the cluster structure of the original MD data. To alleviate this problem, we introduce a novel brushing technique for MDPs called Distortion-aware brushing. While users perform brushing, Distortion-aware brushing correct distortions around the currently brushed points by dynamically relocating points in the projection. Data points close to the brushed points in the MD space are brought closer to the brushed points in the 2D projection, while those further away are repelled. Users can thus brush MD clusters more accurately, conducting more reliable cluster analysis. Our user studies with 24 participants show that Distortion-aware brushing significantly outperforms previous brushing techniques for MDPs in accurately separating clusters in the MD space and is robust against distortions. We also present two use cases demonstrating the effectiveness of our technique in (1) conducting cluster analysis of geospatial data and (2) interactively labeling MD clusters.

Histopathology Image Analysis Using Incomplete and Weak Labels

Won-Ki Jeong
Professor, Korea University

In this research, we proposed to develop various deep learning methods for large-scale histopathology image processing and analysis. Specifically, we intended to develop image classification and segmentation methods only using slide-level labels (weak-label) or incomplete/noisy labels (semi-/self-supervised).

We conducted two research directions, one is weakly-supervised learning for histopathology image classification, and the other is self-supervised learning for image segmentation. As a result of this project, we wrote two research papers, one is published in SPIE Journal of Medical Imaging and the other is submitted to Computers in Biology and Medicine (Elsevier Journal, WoS Ranking Q1) currently under review (minor revision). We expect that the developed methods will greatly reduce the human effort to make training labels manually and improve the classification and segmentation accuracy, comparable to fully supervised methods.

Democratizing Confidential Computing at the Edge through Security-Preserving Optimizations

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Confidential computing at the edge can protect the deep learning models delivered to end-user devices. However, existing trusted execution environment (TEE)-based solutions face significant trade-offs: fully executing deep neural network (DNN) inference within a TEE often restricts execution to CPUs or requires intrusive modifications to proprietary software, while hybrid approaches introduce security gaps or incur high performance overhead due to frequent model obfuscation and TEE-to-REE transitions.

We introduce ASGARD, a virtualization-based TEE framework that democratizes confidential computing at the edge by securing on-device DNNs on legacy Armv8-A SoCs with minimal performance impact and no reliance on proprietary modifications. ASGARD achieves this by: (i) extending TEEs to securely integrate SoC-based accelerators via secure I/O passthrough, (ii) reducing the trusted computing base (TCB) through security-preserving debloating at both platform and application levels, and (iii) optimizing DNN execution to minimize costly TEE-to-REE transitions via exit-coalescing techniques.

Our implementation on an RK3588S-based Android platform with a Rockchip NPU demonstrates that ASGARD provides robust protection for on-device DNNs while maintaining a minimal TCB size and near-zero inference latency overhead. By eliminating the need for proprietary software modifications and reducing security-performance trade-offs, ASGARD paves the way for securityenhanced yet efficient AI computing at the edge, making confidential computing more accessible across diverse edge environments.