

Quantum education required by industry

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LG Electronics

LG Quantum

- To solve biz-related problems in LG
 - By exploring value before the Fault Tolerant Quantum Computing (FTQC) era, *with exponential speedups (aka. Quantum Advantage or Quantum Utility).*
- To contribute to quantum society
 - By building the continuous path toward FTQC using Noise Intermediate-Scale Quantum Computing (NISQ), *from today.*

LG Quantum R&D

- To solve biz-related problems in LG by exploring value before the Fault Tolerant Quantum Computing (FTQC) era, *with exponential speedups*.

Fundamental Quantum Algorithms



Quantum Annealer



Quantum CFD



Optimization



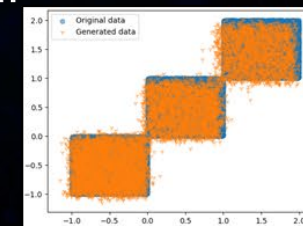
Material Discovery



(2021 Base)

Workforce **75,625** Global Operations **132**

Korea : 37,613 Global : 38,012



Quantum ML



LGE Quantum Team

- *Quantum technology experts, mostly PhDs* in quantum information science, quantum chemistry and quantum physics, with *quantum engineers in practice* who have studied materials science, machine learning, sensors, electronic circuits, etc.

LGE Quantum R&D, Published Papers *from more than 30 papers*

- To solve biz-related problems in LG by exploring value before the Fault Tolerant Quantum Computing (FTQC) era, *with exponential speedups*.
- To contribute quantum society by building the continuous path toward FTQC using Noise Intermediate-Scale Quantum Computing (NISQ), *from today*.

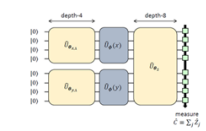
양자기반 "Harmonic Neural Networks" 연구 ICML 2023 논문 게재

다중물리 해석을 위한 양자기반 "Harmonic Neural Networks" 연구 ICML(International Conference on Machine Learning) 2023 논문 게재 확정

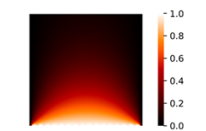
전자 인공지능 연구소는 '21년부터 양자 컴퓨팅 분야에 대한 꾸준한 연구와 투자를 진행 해왔고, 연구 결과를 정리한 'Harmonic Neural Networks' 논문이 시 이론 분야에서 세계 최고 권위의 국제 학회인 'ICML 2023'에 발표로 채택됨

ICML은 올해 40회를 맞은 인공지능 분야 가장 영향력 있는 학회 중 하나로, 다양한 알고리즘의 이론적 기반에 대한 새로운 내용이 발표 됨

본 연구는 조화 함수에 대한 신경망의 귀납 편향을 적용하여 추론 성능을 높였으며, 양자 컴퓨팅 알고리즘으로 확장하여 다양한 응용에 대한 기존의 방식 대비 유용함을 입증하여 새로운 접근 방법의 참신함과 독창성을 인정 받아 논문 게재가 확정됨



Harmonic Quantum NN 양자 회로



Harmonic Quantum NN 이용한 Heat profile

Abstract

Harmonic functions are abundant in nature, appearing in limiting cases of Maxwell's, Navier-Stokes equations, the heat and the wave equation. Consequently, there are many applications of harmonic functions from industrial process optimization to robotic path planning and the calculation of first exit times of random walks. Despite their ubiquity and relevance, there have been few attempts to incorporate inductive biases towards harmonic functions in machine learning contexts. In this work, we demonstrate effective means of representing harmonic functions in neural networks, and extend such results also to quantum neural networks to demonstrate the generality of our approach. We benchmark our approaches against (quantum) physics-informed neural networks, where we show favourable performance.

1. Introduction

Harmonic functions can be defined as the solutions to Laplace's equation $\nabla^2 \phi = 0$, though there are alternative mathematically-equivalent definitions. Such functions are ubiquitous in nature, appearing in limiting cases of Maxwell's equations, the heat (or diffusion) equation, the wave equation, irrotational flow in fluid dynamics and first-hitting times of random walks. Consequently, harmonic

Physical Inductive Biases in Conventional Machine Learning. Of particular relevance to our work on harmonic functions are physics-informed neural networks (PINNs) (Raissi et al., 2019), which use derivatives of neural networks (NNs) with respect to their inputs as a regularization term to provide an inductive bias towards a given differential equation, including potentially towards harmonic functions. Even though this concept was introduced decades ago (Lagaris et al., 1998), PINNs have only recently garnered much attention. For a wider overview of PINNs, we direct the interested reader to a recent review (Karniadaki et al., 2021).

Related to PINNs, there has been a growing recent interest in applying machine learning towards differential equation problems, such as the solution of families of differential equations (Li et al., 2020; Lu et al., 2019), or facilitating the solution via dimensionality reduction (Günzburger et al., 2020). Finding NNs which directly obey a given (linear) differential operator as a hard-constraint has attracted some recent attention (Hendicks et al., 2020). Divergence-free vector fields were also used recently to represent continuity equations (Richter-Powell et al., 2022). We also leverage divergence-free fields in parts of our exposition. In addition to physical inductive biases encodable via differentiable equations, there have also been recently developed methods to effectively impose energy conservation on learnt representations (Grydasos et al., 2019; Cranmer et al., 2020).

Physical Inductive Biases in Quantum Machine Learning. A nontrivial avenue for achieving entanglement




Physics Letters A
Volume 516, 15 August 2024, 129642



Letter

Optimal qubit mapping search for encoding classical data into matrix product state representation with minimal loss

양자 어닐링 OLED 고효율 발광 소재 신조성 탐색 연구 JPS Journals에 논문 게재



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Virtual Screening of Chemical Space Based on Quantum Annealing

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Portable, Miniaturized Quantum Magnetometer and Educational Quantum Platform based on Diamond NV Center

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Introduction

- Quantum sensing platform works in ambient condition
- Highly sensitive to magnetic field, can be miniaturized

Project 1: Mark Mini_Portable Magnetometer

- Progress in size & sensitivity



LGE Quantum R&D, Workforce Perspectives

- Quantum technology is recognized as very important technology for corporate.
- The technological stage represents a crucial transition from quantum science to quantum engineering to achieve quantum utility.
- **Quantum technology itself is a huge field to understand due to the variety of platforms (superconductivity, neutrons, photonics, etc.).**

양자 기반 "Harmonic Neural Networks" 연구 ICML 2023 논문 게재

• **Quantum CFD**

— **Uses algorithms and new tools that utilize quantum mechanics, which are different from classical computing technologies**

— **A unique approach is needed to secure and train specialized human resources.**

Harmonic Quantum NN
양자 회로

Harmonic Quantum NN
이용한 Heat profile

• **Quantum ML**

— **It is questionable whether Quantum ML is competitive enough when compared to classical AI / ML.**

— **From the standpoint of a classical SW engineer, it is not evident which algorithmic approach is oriented toward practical applications.**

양자 에너지 저장 및 수송을 위한 소재 시조성 탐색 연구 JPS Journals에 논문 게재

• **Material Discovery**

— **It is difficult to calculate the properties of industrially meaningful materials using NISQ.**

— **It is critical to define the problems, which are really difficult for classical computers and AI, and yet simple enough for NISQ.**

Virtual Screening of Chemical Space Based on Quantum Annealing

• **Quantum Sensor**

— **The majority of the workforce in the enterprise, e.g., professionals with backgrounds in materials/chemistry, electronics, computer science, etc., have a low understanding of quantum technology.**

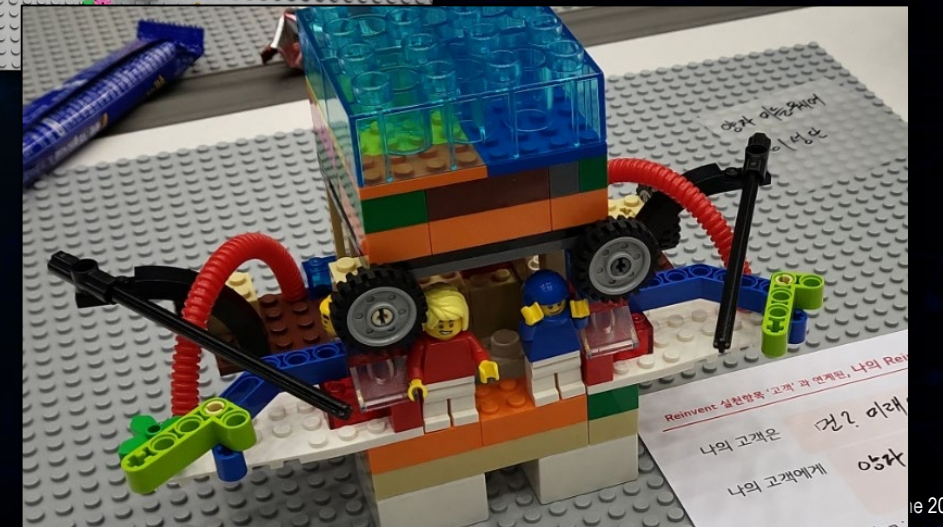
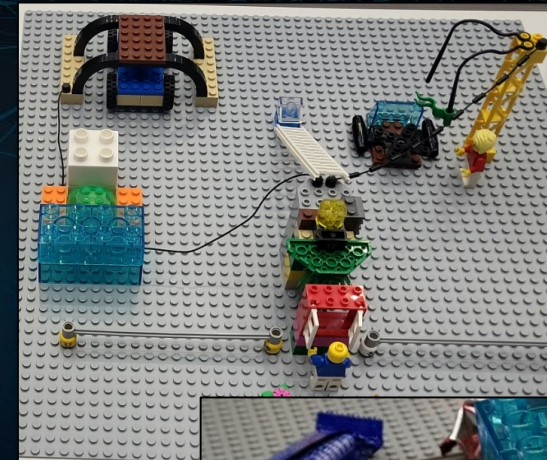
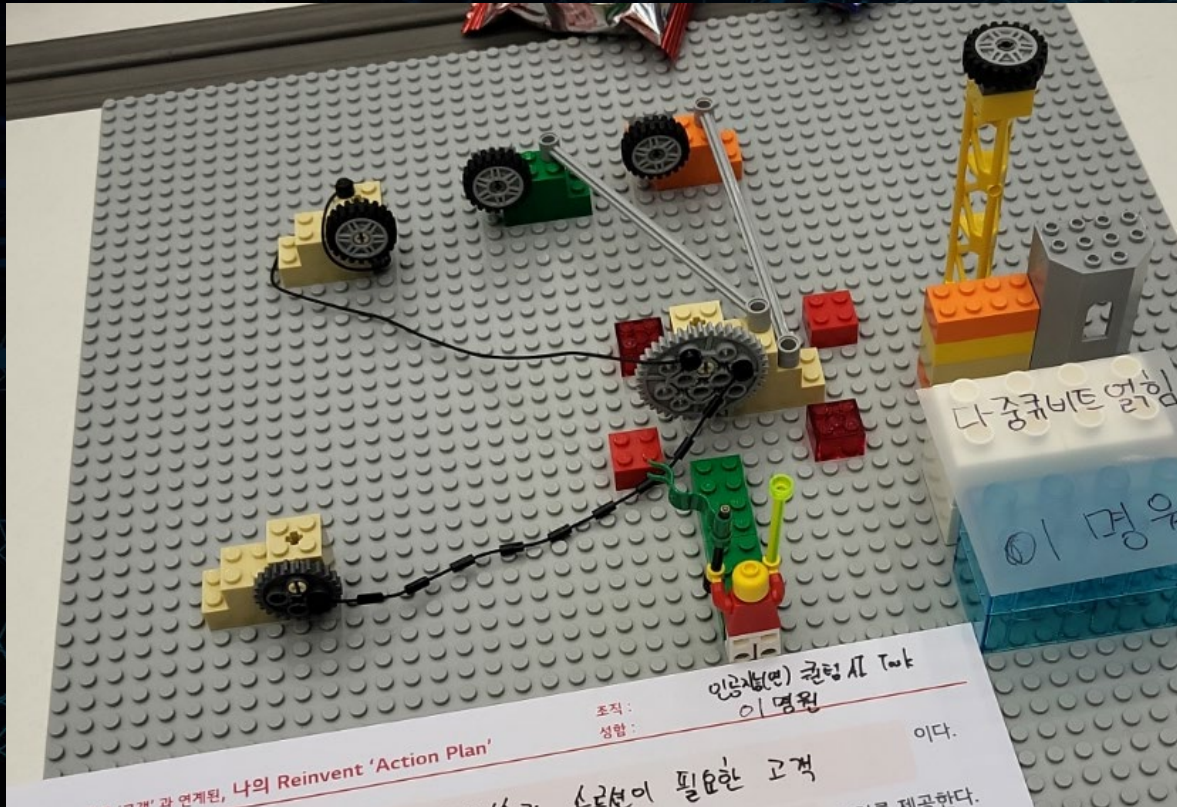
— **From engineering perspectives, since all quantum technologies are so integrated, it is difficult to understand all of them, even for experts who majored in quantum physics.**

Portable Miniaturized Quantum Magnetometer and Educational Quantum Platform based on Diamond NV Center



LGE Quantum LEGO® SERIOUS PLAY ('2023)

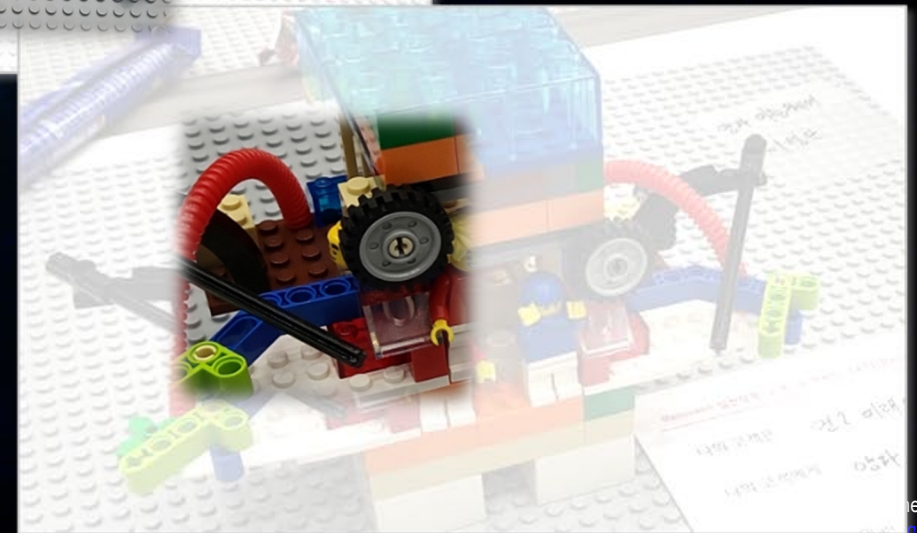
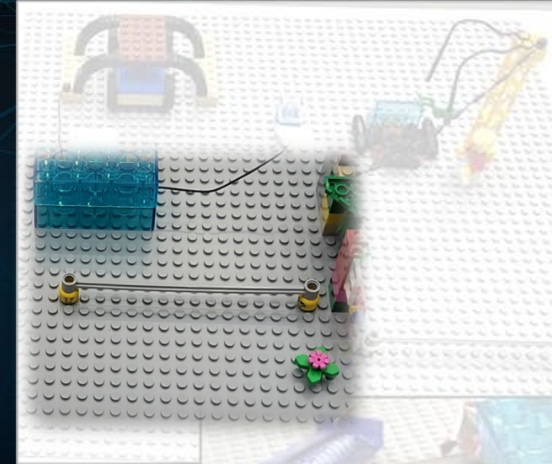
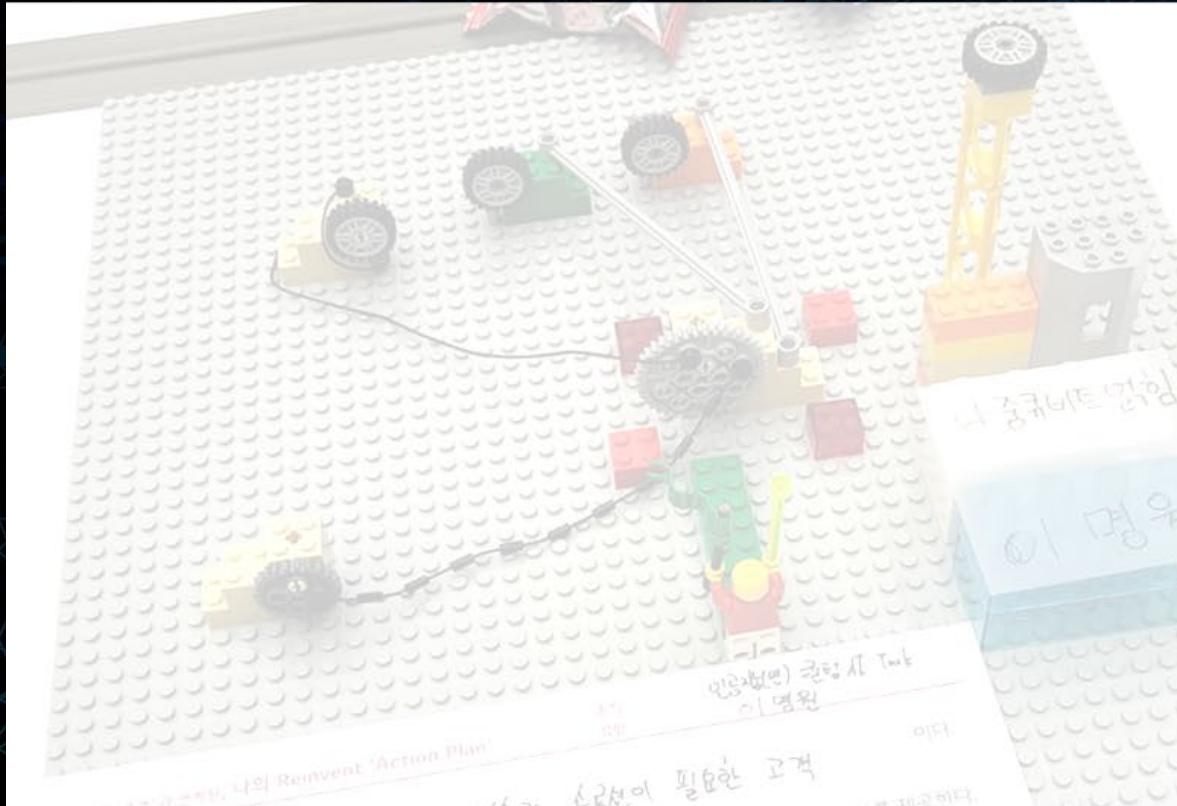
- LEGO® SERIOUS PLAY is a facilitated process that uses LEGO elements to encourage dialogue, reflection, and problem-solving skills.
- It is a method for facilitating communication in meetings, facilitating thinking, and problem-solving ideas for individuals, teams, and organizations.



Team Lego Serious Play (Dec. 18, 2023)

LGE Quantum LEGO® SERIOUS PLAY ('2023)

- LEGO® SERIOUS PLAY is a facilitated process that uses LEGO elements to encourage dialogue, reflection, and problem-solving skills.
- It is a method for facilitating communication in meetings, facilitating thinking, and problem-solving ideas for individuals, teams, and organizations.



레고플레이 활동 중 조직 Mission, R&R ('23. 12. 18)

Takeaways and Wrap Up (1/2)

- **As a latecomer in the field of quantum computing, securing and educating specialized human resources is an important topic to secure a global competitive advantage and create a R&D ecosystem.**
- **As a corporate research institute conducting R&D in Quantum Computing,**
 - Our objective is to facilitate the acquisition of insights into the latest technology trends through collaboration with advanced companies and universities and the development of new algorithms and hardware.
 - We seek to identify areas of quantum computing that have significant business impact within companies and to provide a practice-oriented continuous R&D environment and accumulate capabilities.
 - Finally, participation in national projects with universities, research institutes, and companies can be utilized as a good opportunity to invest in quantum computing technology and to secure research manpower, which is still highly uncertain.

Takeaways and Wrap Up (2/2)

- **Despite the limitations of FTQC, we believe it may offer a potential advantage in addressing certain problems that classical computers are unable to resolve effectively.**
 - From this perspective, it is crucial to clearly identify the complex problems that are currently beyond the capabilities of classical computers.
 - In order to identify a problem that is genuinely challenging for a classical computer, it is necessary to have experience in dealing with a particularly difficult problem using a classical computer.
- **In conclusion, it would be advantageous to have a talent with quantum algorithm/computation expertise, based on experience with actively using classical high-performance computers (HPCs) and addressing associated challenges.**