AI Seminar Report

Date: 03/28/2025

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School	Dongguk University	**Course Classification**	Ph.D.
Speaker Name	진경환 부교수	**Speaker Affiliation**	고려대학교
Title	Towards Lossless Digital Imaging World: Quantization-Aware Deep Neural Networks		

■ Seminar Contents

I. Foundational Concepts: Continuous vs. Discrete Representation

- **Representation Domains:** We distinguish between the continuous domain, reflecting real-world signals, and the discrete domain, representing digital information.
- **Domain Transition:** Mapping from the continuous to the discrete typically involves sampling followed by quantization.
- **Quantization:** Formally, quantization is a function mapping a continuous input space (X) to a finite set of discrete output levels (Q_n), often utilizing methods like ceiling quantization to discretize analog functions.
- **Quantization-Aware Processing:** Systems designed for the discrete world often incorporate both quantization and de-quantization steps, particularly relevant for numerical representations like FP16/FP32 floating-point formats.

II. Paper 1: Lossless Implicit Neural Representations via Bit Plane Decomposition (CVPR 2025)

- **Objective:** To achieve lossless signal representation using Implicit Neural Representations (INRs).
- **Methodology:** Proposes Bit-Plane Decomposition, where an INR maps input coordinates (and potentially associated bit coordinates) to individual bit planes of the target signal.
- **Training Paradigm:** The INR is supervised to reconstruct the original signal accurately from the predicted bit planes.
- **Theoretical Contributions:**
    - Establishes an upper bound on the necessary INR parameter count relative to the target bit precision.
    - Identifies and analyzes "bit bias" and "bit-spectral bias," phenomena within the bit-plane domain analogous to spectral bias in standard INRs.

- **Key Findings & Performance:**
  - Achieves perfect reconstruction (infinite PSNR) for low bit depths (1-4 bits) and exceptionally high fidelity (PSNR > 100) for 8 bits.
  - Observes faster training convergence for lower bit-precision targets.
  - Demonstrates superior performance compared to state-of-the-art methods in terms of convergence speed and reconstruction accuracy.
- **Significance & Applications:** The approach facilitates lossless representation in digital media, with potential applications in ternary networks, lossless compression algorithms, and bit-depth expansion tasks.

III. Paper 2: Grid-wise Addressable Memory (GAM) (submitted)

- **Objective:** To develop 'Memory-Integrated' Implicit Neural Representations that are capable of lossless data storage and retrieval.
- **Conceptual Framework:** Integrates memory directly within the INR, visualized as storing data points within a stable energy landscape.
- **Methodology & Theory:**
  - Employs principles derived from Lyapunov stability theory to ensure reliable data retrieval.
  - Utilizes recurrent stable training dynamics, potentially enforcing monotonic gradient descent for convergence to stored states.
  - Investigates quantized representations within GAM, analyzing the interplay between bit-level discontinuities and smoother gray-level representations.
- **Key Findings & Performance:**
  - Realizes stable, addressable memory functionality within the implicit function.
  - Achieves perfect reconstruction of stored data.
  - Demonstrate training efficiency, requiring fewer iterations to attain high PSNR compared to alternative approaches.
- **Applications:**
  - Successfully applied to representing complex signals, such as Signed Distance Functions (SDFs).
  - Shown to be adequate for tasks such as Novel View Synthesis, leveraging its data retrieval capabilities.

■ What have you learned from this seminar?

- **Bridging Worlds:** I gained a clearer understanding of how we translate continuous, real-world information into the discrete, digital domain, primarily through sampling and quantization.
- **Lossless INRs:** Explored cutting-edge techniques using Implicit Neural Representations (INRs) to achieve lossless data representation, moving beyond typical approximation methods.
- **Bit-Plane Strategy:** Learned about a specific approach (Bit-Plane Decomposition) that cleverly breaks down signals into individual bit layers for an INR to learn, enabling perfect reconstruction, especially at lower bit depths.
- **Memory in INRs:** Understood a novel concept (Grid-wise Addressable Memory - GAM) that integrates memory directly within an INR, using stability principles for perfect data storage and retrieval.
- **Theoretical Insights:** Appreciated the theoretical work presented, including the establishment of bounds on model size based on precision and the identification of phenomena such as "bit bias."
- **Efficiency Matters:** It is noticeable that both presented methods emphasize efficient training, achieving high performance (such as perfect reconstruction or high PSNR) faster than previous approaches.
- **Practical Potential:** Recognized the broad applicability of these advanced INR techniques in areas such as lossless compression, complex signal representation (e.g., SDFs), and even novel view synthesis.

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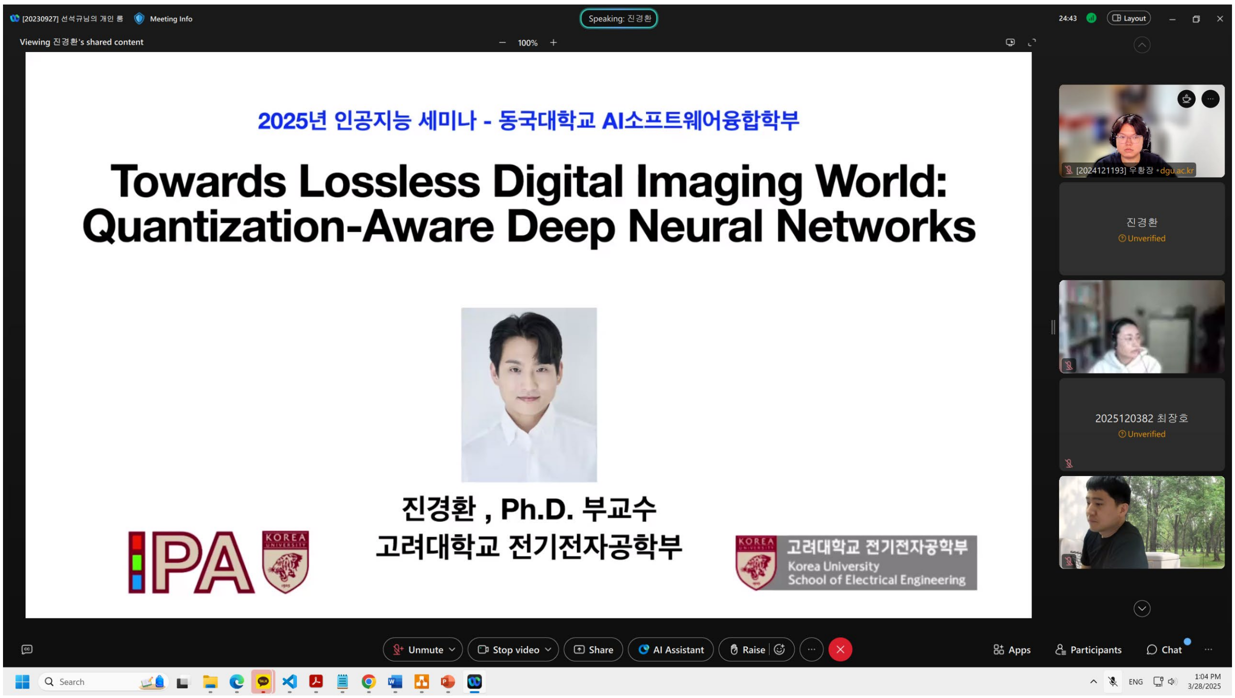

Capture your Webex screen showing the end time as well.