

Assignment 1: The Limits and Evolution of Recurrent Architectures

Course COMP5801H/4900A: Generative AI and LLMs

Release Date: January 16, 2026 — **Due Date:** January 29, 2026

Objective

To critically evaluate the architectural choices in sequential modelling through mathematical reasoning, literature review, and lightweight empirical testing.

Questions

There are six questions provided below, each containing one assertion. Respond to **any three** questions from the six provided.

Collaboration

All **graduate and undergraduate students** (i.e., belonging to COMP5801H or COMP4900A) will complete and submit the assignment **individually**.

Format

For each of the questions, you must take a stand: **Agree** or **Disagree** with the provided assertion. You must support your position with a combination of:

- **Mathematical Justification:** Formal analysis of update equations, gradients, and/or gate mechanisms.
- **Experimental Justification:** Plots generated from scripts carrying out the experiments, along with detailed analysis/interpretation of the results.

For each position you take, you are required to provide at least **two strong** independent evidences. One of these evidences could involve a mathematical justification. So, if you are providing two evidences for a question, it could be either one mathematical justification and one experimental justification or two different experimental justifications. *Experimental investigations conducted across two different datasets comprising significantly distinct feature sets will be evaluated as two separate and independent pieces of empirical justification.* You should justify how the two datasets provide fundamentally “different” insights into the architecture. For every justification, it is not sufficient to only show the result (in terms of an equation or a plot). You should clearly explain the result and elucidate how that result serves as a **strong evidence** to the position that you have taken.

For the experimental investigations, you are strongly encouraged to design simple, targeted experiments (roughly plan for experiments that can be executed on a standard laptop CPU); the focus should be on providing clear analysis and insights from the results rather than complex training runs requiring multiple GPUs. Any experimentation that relies on stochasticity or randomization should provide results involving at-least three different random seeds, along with the average and standard deviation of performance measures.

For every question, make sure to reference **at least two** academic papers to strengthen your arguments.

Submission Instructions

All materials must be submitted via **Brightspace** no later than **January 29, 11:59 PM ET**. Your submission must include:

1. **Formal Report:** A PDF document containing your stance on each assertion, mathematical derivations (as appropriate), experimental plots, associated discussions of the results (clarifying how they support your assertion), and academic citations. See “Grading Criteria” below for more details. Make sure to include the **question number** from this document for the selected three questions, so that the assertion you are responding to is clear to the grader.
2. **Implementation Files:** All source code used for the experiments. The experiments must be reproducible using the provided code. Include a **README** file providing clear instructions on how to run the scripts and generate the results. Include comments in your code as appropriate. The code can also be provided in Jupyter notebook files. The code should be runnable as submitted (they **cannot** be submitted in word or PDF documents).

Question 1: The “Death” of the LSTM

Assertion: “With the rise of the Transformer and its parallelization capabilities, the LSTM is now a purely historical architecture with no remaining practical utility in Generative AI.”

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Question 2: The GRU’s Efficiency vs. Representation

Assertion: “The GRU’s decision to merge the Forget and Input gates into a single Update Gate (z_t) is a mathematical shortcut that inherently limits its ability to model complex hierarchical languages compared to the LSTM.”

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Question 3: Vanishing Gradients as a “Hard” Ceiling

Assertion: “The Vanishing Gradient problem is a fundamental limitation of the *recurrent paradigm* that can only be mitigated by gating, never fully solved as long as the architecture relies on the Hidden State (h_t).”

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Question 4: Markov Assumption vs. Persistent State

Assertion: “The notion of ‘Memory as a Loop’ (Recurrence) is unnecessary, we can achieve superior results by treating all sequences as high-order N-Grams using the Markov Assumption.”

Q5: The Real-Time Constraint of Bi-RNNs

Assertion: “While Bidirectional RNNs (Bi-RNNs) provide a superior contextual understanding compared to Unidirectional RNNs, they are mathematically incapable of real-time stream processing (online inference).”

Question 6: The Depth Bottleneck

Assertion: “Increasing the depth of an RNN by stacking layers provides diminishing returns and eventually destabilizes training, more than increasing the depth of a Feed-Forward Network.”

Grading Criteria

- **Strength of the evidences (45%):** Is the position clearly stated? Are there at-least two strong evidences for the position taken? Are the evidences appropriate for the stated position? Are there any technical errors in the arguments provided?
- **Clarity of report (45%):** Experimental investigations must be clearly explained (i.e., the dataset used, hyperparameters selected, the experimental procedure followed, and rational for the choices), plots need to be clear (clear labelling of axes and legends), and all terms/variables of an equation should be clarified for theoretical justifications. If a derivation is performed, each step of the derivation should be clarified. All equations should be clearly explained in words. The results of an experimental investigation must be clearly explained. For both mathematical and empirical results, reasons for how these results support the stated position should be clearly explained. There are no page limits to the report, just make sure that all justifications are clear, without ambiguities or confusions.
- **Implementation (0%):** Are empirical results reproducible from the submitted implementation files and provided instructions? The implementation files do not carry any points, but if the results are not reproducible, the empirical evidences in your report will **not be awarded** any points. To ensure the reproducibility of your empirical findings, any experimentation involving randomization must clearly specify the random seeds and environment configurations used.
- **Literature citations (10%):** Do the provided literature references strengthen the arguments presented?

Reminder: Course Policy on Generative AI Tool Usage

You are free to use any Generative AI Tool for your assignments or projects in the course, but you bear responsibility for all your submissions. Since Generative AI tools may plagiarize from other

sources on the web, you should be extremely careful while using them. They are also prone to producing incorrect information with exaggerated confidence. All prior work should be rigorously cited, and any plagiarism will be considered an academic offence.